MGS Flood
Users Manual

A Continuous Hydrological Simulation Model for Stormwater Facility Analysis

Washington State Department of Transportation

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Prepared for

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1 INTRODUCTION

MGSFlood is a general, continuous, rainfall-runoff computer model developed specifically for stormwater facility design in Western Washington. The program uses the Hydrological Simulation Program-Fortran (HSPF)[26] routine for computing runoff from rainfall. The program includes a routing routine that uses a stage-storage-discharge rating table to define a stormwater retention/detention facility or reservoir, routines for computing streamflow magnitude-frequency and duration statistics, and graphics routines for plotting hydrographs and streamflow frequency and duration characteristics. The program meets the requirements of the 2001 Washington State Department of Ecology Stormwater Management Manual for Western Washington[9].

2 MGS Flood Model Applicability, Limitations and Program Configuration

2.1 Model Applicability and Limitations

MGSFlood is intended for the analysis of stormwater detention facilities in the lowlands of western Washington. The program utilizes the HSPF routines for computing runoff from rainfall for pervious and impervious land areas. The program does not include routines for simulating the accumulation and melt of snow and its use should be limited to lowland areas where snowmelt is typically not a major contributor to floods or to the annual runoff volume. In general, these conditions correspond to an elevation below approximately 1500 feet.

The program was designed for the analysis of detention facilities for small-scale development and is applicable to either road or land development projects. The program is currently provided with precipitation timeseries at a 1-hour timestep, which is appropriate for stormwater detention design only. Precipitation input at a shorter timestep (15-minutes) would be needed to accurately estimate the peak runoff rate needed for sizing of conveyance structures for small-scale development projects and the design of water quality treatment facilities that depend on runoff rate. Thus, the program should not be used for conveyance design unless the conveyance system is downstream of a stormwater detention pond, where regulation of streamflow renders a 1-hour time-step sufficiently accurate for conveyance design.

The program provides acceptable results for sites up to about 320 acres in size (one-half square mile). The limitation on the maximum allowable size of the site to be analyzed is due to the manner in which channel routing in the stream network is addressed. Since the primary application of the model is for small-scale sites, channel routing was not included in the model. The attenuating effect of channel routing on flood peak discharge becomes increasingly more important as the size of the watershed and complexity of the stream network increases. Application of the program to larger watersheds may result in an overestimation of peak runoff due to improperly accounting for routing effects.

If the site of interest is large, contains multiple stormwater facilities in series, or involves routing through a natural lake, pond or wetland in addition to a stormwater control facility, then the user should use a watershed scale model such as HSPF[26].

2.2 Disclaimer

MGSFlood is a complex program that requires engineering expertise to use correctly. MGS Engineering Consultants, Inc. and the Washington State Department of Transportation assumes absolutely no responsibility for the correct use of this program. All results obtained should be carefully examined by an experienced professional engineer to determine if they are reasonable and accurate.

Although MGS Engineering Consultants, Inc. has endeavored to make this program error free, the program is not and cannot be certified as infallible. Therefore, MGS Engineering Consultants, Inc. or the Washington State Department of Transportation makes no warranty, either implicit or explicit, as to the correct performance or accuracy of this software.

In no event shall MGS Engineering Consultants, Inc. or the Washington State Department of Transportation be liable to anyone for special, collateral, incidental, or consequential damages in connection with or arising out of use of this program.

2.3 Program Configuration

Figure 2.1 shows a schematic of the MGSFlood modeling package. The main program module, MGSFlood.exe, controls the user interface, HSPF, statistics, routing, and pond optimization routines. When the program starts, the location of the program and project subdirectories on the computer system is read from a Microsoft Access database file called MGSFloodinit.mdb. Project data files have a user specified name and a *.fld* extension. These files are also Microsoft Access database files and are stored in the project subdirectory.

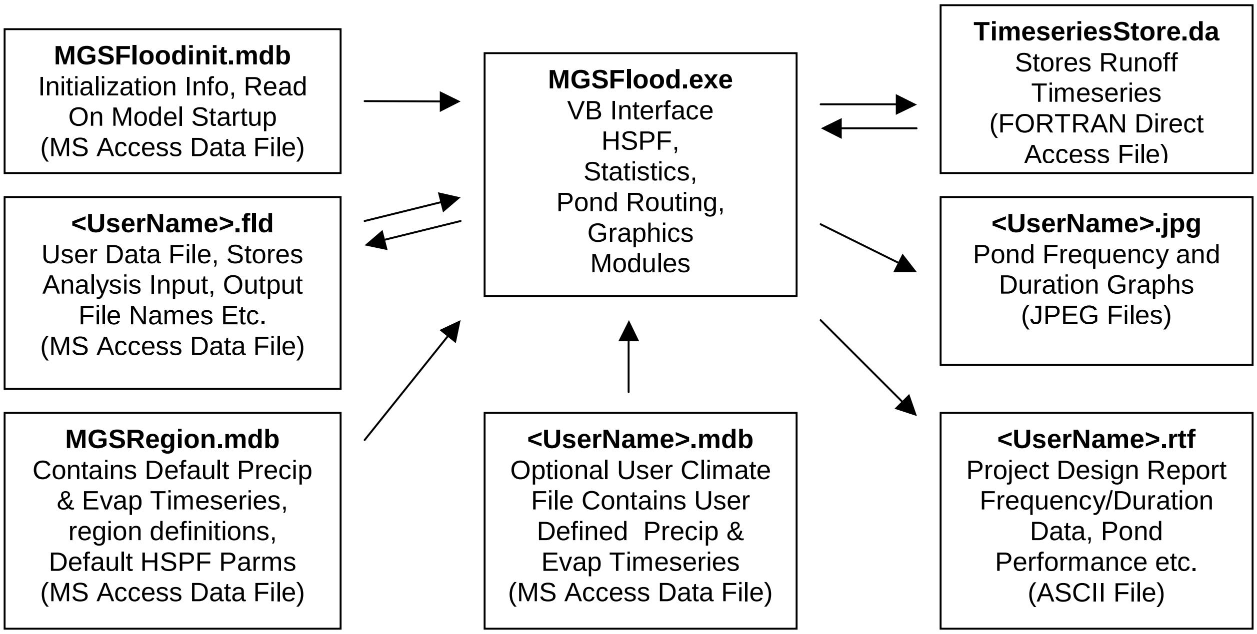

Figure 2.1 – MGSFlood Model Components

2.4 Precipitation and Evaporation Input

MGSRegions.mdb is an Access database file that contains the precipitation and evaporation timeseries for each region, and the default HSPF parameters.

2.5 Runoff Data File

Runoff is computed by MGSFlood using the HSPF[26] library routine. Precipitation and evaporation are read from the MGSRegion.mdb file, runoff is computed for predevelopment and postdevelopment conditions, and saved to a FORTRAN, binary, direct access file called TimeseriesStore.da. The same FORTRAN direct access file is overwritten for each project analyzed by the flood model, i.e. the computed runoff timeseries are not saved for each project. Thus, the project runoff must be recomputed before performing any pond design iterations to ensure that the TimeseriesStore.da file is up-to-date and contains runoff for the project currently under consideration.

2.6 Project Documentation and Graphics Files

Project documentation is stored in an ASCII file in the project subdirectory with an *.rtf* extension. This file is created/overwritten each time the report is written by the program.

Files containing images of graphs plotted on the screen are also stored in the project subdirectory. These files are *JPEG* format and contain the latest images of hydrograph, flood frequency, and flow duration plots plotted by the program. The JPEG graphic images can be imported into any software that accepts the JPEG format. This feature is intended to support importing graphics into word processing programs for preparation of reports and other documents.

3 HSPF Runoff Routine and Runoff Parameters

MGS Flood uses the rainfall-runoff routine from the Hydrological Simulation Program-Fortran (HSPF)[26]. HSPF uses multi-year inputs of hourly precipitation and evaporation, keeps a running accounting of the moisture within the soil column and in groundwater storage, and simulates a multi-year timeseries of hourly runoff.

3.1 Pervious Land Parameters

Default HSPF model parameters that define interception, infiltration, and movement of moisture through the soil, are based on work by the USGS[7,8] and King County[17]. Pervious areas have been grouped into three land cover categories; forest, pasture, and lawn, and three soil/geologic categories; till, outwash, and saturated/wetland soil for a total of seven cover/soil type combinations as shown in Table 3.1. The combinations of soil type and land cover are called *pervious land segments* or *PERLNDS*. Default runoff parameters for each PERLND are summarized in Table 3.2. These values are loaded automatically by the program for each project. If these values are changed by the user, the changed values are noted in the project documentation report (See Section 10).

Table 3.1 - Pervious Land Soil Type/Cover Combinations used with HSPF Model Parameters

Pervious Land Soil Type/Cover Combinations
1. Till/Forest
2. Till/Pasture
3. Till/Lawn
4. Outwash/Forest
5. Outwash/Pasture
6. Outwash/Lawn
7. Saturated Soil/All Cover Groups

Table 3.2 – Default Runoff Parameters for Each Pervious Land Segment (PERLND)

	Pervious Land Segment (PERLND)						
	Till Soil			Outwash Soil			Saturated Soil
Parameter	**Forest**	**Pasture**	**Lawn**	**Forest**	**Pasture**	**Lawn**	**Forest/Pasture/ or Lawn**
LZSN	4.5	4.5	4.5	5.0	5.0	5.0	4.0
INFILT	0.08	0.06	0.03	2.0	1.6	0.8	2.0
LSUR	400	400	400	400	400	400	100
SLSUR	0.1	0.1	0.1	0.05	0.05	0.05	0.001
KVARY	0.5	0.5	0.5	0.3	0.3	0.3	0.5
AGWRC	0.996	0.996	0.996	0.996	0.996	0.996	0.996
INFEXP	2.0	2.0	2.0	2.0	2.0	2.0	10.0
INFILD	2.0	2.0	2.0	2.0	2.0	2.0	2.0
BASETP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AGWETP	0.0	0.0	0.0	0.0	0.0	0.0	0.7
CEPSC	0.2	0.15	0.1	0.2	0.15	0.1	0.1
UZSN	0.5	0.4	0.25	0.5	0.5	0.5	3.0
NSUR	0.35	0.3	0.25	0.35	0.3	0.25	0.5
INTFW	6.0	6.0	6.0	0.0	0.0	0.0	1.0
IRC	0.5	0.5	0.5	0.7	0.7	0.7	0.7
LZETP	0.7	0.4	0.25	0.7	0.4	0.25	0.8

PERLND parameter definitions:
LZSN =lower zone storage nominal (inches)
INFILT =infiltration capacity (inches/hour)
LSUR =length of surface overland flow plane (feet)
SLSUR =slope of surface overland flow plane (feet/feet)
KVARY =groundwater exponent variable (inch $^{-1}$)
AGWRC =active groundwater recession constant (day $^{-1}$)
INFEXP =infiltration exponent
INFILD =ratio of maximum to mean infiltration
BASETP =base flow evapotranspiration (fraction)
AGWETP =active groundwater evapotranspiration (fraction)
CEPSC =interception storage (inches)
UZSN =upper zone storage nominal (inches)
NSUR =roughness of surface overland flow plane (Manning 's n)
INTFW =interflow index
IRC =interflow recession constant (day $^{-1}$)
LZETP =lower zone evapotranspiration (fraction)

A complete description of the PERLND parameters can be found in the HSPF User Manual[26]. Default PERLND Parameters used in the model were developed for the Puget Sound Lowlands by the US Geological Survey[7,8]

3.2 User Defined Pervious Land Segments

Up to four additional Pervious Land Segments (PERLNDs) may be specified by the user by opening the HSPF Parameter sheet and clicking the *New* button at the bottom of the page. A window will appear with parameter fields for up to four additional PERLNDs. The user can specify the name of these as well as the HSPF parameters. This feature allows the user to define land cover/soil type combinations not included in the default parameters. Once the "Active" checkbox is checked and the parameters have been defined for each user-defined PERLND, the user-defined PERLND will be active on the subbasin area window.

3.3 Impervious Land Parameters

Default runoff parameters for impervious surface, called *IMPLNDs* are summarized in Table 3.3.

Table 3.3 – Impervious Cover (IMPLND) Parameters

Parameter	Value
LSUR	100
SLSUR	0.01
NSUR	0.1
RETSC	0.1

IMPLND Parameter Definitions:
LSUR = length of surface overland flow plane (feet)
SLSUR = slope of surface overland flow plane (feet/feet)
NSUR = roughness of surface overland flow plane (Manning 's n)
RETSC = retention storage (inches)

A complete description of the IMPLND parameters can be found in the HSPF User Manual[26].
IMPLND Parameters were developed for the Puget Sound Lowlands by the US Geological Survey[7,8]

3.4 Determining PERLND Soil Type from SCS Soil Mapping

The soils at the project site must be classified into one of the three default categories for use in the MGSFlood model. These soils categories are: till, outwash, or saturated soil, as defined by the USGS[7,8].

Soils formed in areas with glacial till are underlain at shallow depths by relatively impermeable glacial till (also known as "hard-pan"). Glacial till deposits contain large percentages of silt or clay and have low percolation rates. Only a small faction of infiltrated precipitation reaches the groundwater table. The rest moves laterally through the thin surface soil above the till deposit as interflow. Shallow soils over bedrock should also be classified as till soils because the hydrologic response from these areas is similar to till.

Soils formed in areas with glacial outwash deposits consist of sand and gravels that have high infiltration rates. The majority of rainfall is infiltrated and percolates to the groundwater table. Creeks draining outwash deposits often intersect the groundwater table and receive most of their flow from groundwater discharge. Site developments in outwash areas are typically located higher in the watershed and groundwater discharge is not present. Thus, groundwater is typically not included in runoff calculations in outwash (or till) areas.

Wetland soils remain saturated throughout much of the year. The hydrologic response from wetlands is variable depending on the underlying geology, the proximity of the wetland to the regional groundwater table, and the bathymetry of the wetland. Generally, wetlands provide some baseflow to streams in the summer months and attenuate storm flows via temporary storage and slow release in the winter.

Mapping of soil types by the Soil Conservation Service (SCS, now the National Resource Conservation Service (NRCS)) is the most common source of soil/geologic information used in hydrologic analyses for stormwater facility design. Each soil type defined by the SCS has been classified into one of four hydrologic soil groups; A, B, C, and D. As is common practice in hydrologic modeling in western Washington, the soil groups used in the MGSFlood model generally correspond to the SCS hydrologic soil groups as shown in Table 3.4.

Table 3.4 – Relationship Between SCS Hydrologic Soil Group and MGS Flood Soil Group

SCS	MGS Group
A	Outwash
B	Till or Outwash
C	Till
D	Wetland

SCS Type B soils can be classified as either glacial till or outwash depending on the type of soil under consideration. Type B soils underlain by glacial till or bedrock, or have a seasonally high water table would be classified at till. Conversely, well-drained B type soils would be classified as outwash.

The Ecology Stormwater Management Manual for Western Washington[9] relates SCS hydrologic soil groups to HSPF soil/geologic groups as shown in Table 3.5

Table 3.5 – Relationship between SCS and HSPF Soil Groups

SCS Hydrologic Soil Group	MGSFlood/HSPF Soil/Geologic Group
A/B	Outwash
C	Till
D	Wetland

4 Precipitation Input

MGSFlood uses multi-year inputs of hourly precipitation and evaporation to compute a multi-year timeseries of runoff from the site. Using precipitation input that is representative of the site under consideration is critical for the accurate computation of runoff and the design of stormwater facilities. Precipitation and evaporation timeseries have been assembled for most areas of western Washington and are stored in a database file accessed by the program. These timeseries should be used for stormwater facility design.

4.1 Selection and Scaling of Precipitation for Stormwater Facility Design

Accurate assessment of streamflow characteristics at a particular site is dependent upon numerous watershed and hydrometeorological factors. Among those factors, it is critically important to have a precipitation timeseries representative of the climatic and storm characteristics at the site of interest. However, it is rare that a long precipitation timeseries is available at the site of interest. This problem is commonly addressed by transposing the timeseries record from a "nearby" gage to the site of interest using some type of scaling routine to account for the differences in storm characteristics at the source and target sites.

Proper transposition is a very complex problem as storm characteristics vary by both duration and physical topographic setting across western Washington. For example, a site with a mean annual precipitation of 50-inches to the west of central Puget Sound has different precipitation magnitude-frequency characteristics than a site with 50-inches mean annual precipitation located to the east of central Puget Sound. Ideally, a dense network of hourly precipitation gages would be available and only minor amounts of scaling would be needed. Unfortunately, only a limited number of long-term, high quality hourly precipitation recording stations are available in western Washington. Therefore, the transposition of timeseries by scaling is a critical aspect of obtaining a representative timeseries for most sites.

Two methods of transposing precipitation timeseries are available in the MGSFlood model. The first method utilizes a family of pre-scaled precipitation and evaporation timeseries. These precipitation timeseries were developed using statistical scaling functions to scale hourly precipitation amounts for eight selected inter-durations within the timeseries. This method was used to produce "extended precipitation timeseries" with record lengths in excess of 100-years by combining and scaling precipitation records from widely separated stations[21,22]. Extended hourly precipitation and evaporation timeseries have been developed using this method for most of the lowland areas of western Washington where stormwater projects will be constructed. These timeseries should be used for facility design for projects located in the region shown in Figure 4.1.

For projects sites located outside of the extended timeseries region, a second precipitation scaling method is used. This method uses a simple scaling procedure that scales all hourly precipitation amounts in the source timeseries by a common scaling factor. Use of these two methods is described in the following sections.

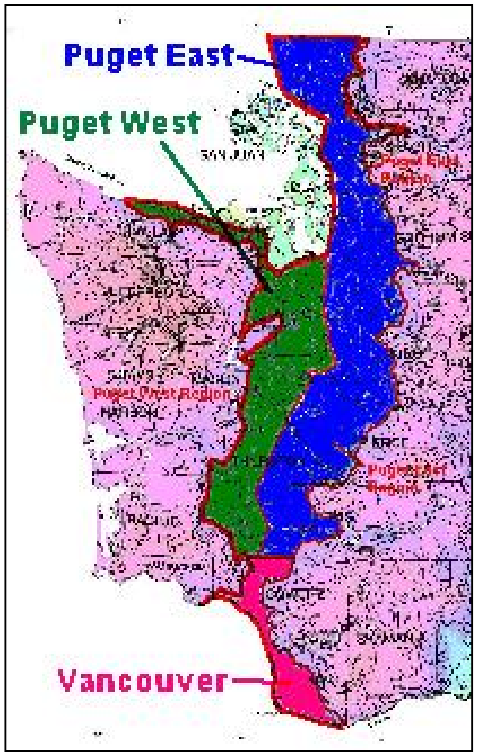

Figure 4.1 – Extended Precipitation Timeseries Regions

4.1.1 Extended Precipitation Timeseries

Extended, hourly precipitation and evaporation timeseries have been developed for most of the lowland areas of western Washington where stormwater projects will be constructed. This collection of 22 timeseries is applicable to sites with mean annual precipitation ranging from 32-inches to 60-inches in the lowlands from the Canadian border to the Oregon border. The timeseries are grouped according to region; Puget West, Puget East, and Vancouver. An additional 15 timeseries applicable to sites with mean annual precipitation ranging from 38 to 52 inches was included for project sites located in Pierce County.

The extended precipitation and evaporation timeseries are either 121-years or 158-years in length. The precipitation timeseries were developed by combining and scaling records from distant precipitation stations. The precipitation scaling was performed such that the scaled precipitation record would possess the regional statistics at durations of 2-hour, 6-hours, 24-hours, 3-days, 10-days, 30-days, 90-days, 6-months and annual. The evaporation timeseries were developed using a stochastic evaporation generating approach whereby daily evaporation was generated in a manner to preserve the daily and seasonal variability and accounting for differences observed on rainy versus rain-free days. The evaporation timeseries were developed from data collected at the Puyallup 2 West Experimental Station (station number 45-6803). Details on the development of the precipitation and evaporation timeseries can be found in the report; *Extended Precipitation Time-Series for Continuous Hydrological Model in Western Washington*, MGS Engineering Consultants, Inc., 2002[20].

Precipitation Input Selection Example

A project site is located in Thurston County as shown in Figure 4.2. The Project Site is located in the Puget Sound West region with a mean annual precipitation of 51 inches. From the Climatic Region drop down box, select the extended precipitation timeseries for the western Puget Sound Region with mean annual precipitation closest to the project site. In this case, select Puget Sound West Region, 52 inches MAP.

Figure 4.2 – Extended Precipitation Timeseries Selection Example

4.1.2 Single Scaling Factor Approach

For projects sites located outside of the extended timeseries region, a *source* gage is selected and a single scaling factor is applied to transpose the hourly record to the site of interest (target site). The current approach for single scaling, as recommended in the *Stormwater Management Manual for Western Washington*[9], is to compute the scaling factor as the ratio of the 25-year 24-hour precipitation[21] for the target and source sites:

$$Scale\ Factor = P_{25\ TargetSite}/P_{25\ SourceGage} \tag{4.1}$$

where: $P_{25\ TargetSite}$ = 25-year 24-hour precipitation at the project site of interest (entered by user)

$P_{25\ SourceGage}$ = 25-year 24-hour precipitation at the source gage (provided by program)

The values of the 25-year 24-hour precipitation may be obtained from NOAA Atlas #2[18] or from the recently released WSDOT update of precipitation-frequency information for western Washington[21]. To utilize the recently updated precipitation-frequency information for western Washington, open the *Precipitation Map* from the *Project Location Tab*. Regions of influence for each gage are identified on the map along with the 25-year 24-hour precipitation. Choose the precipitation region where the project site is located. Read the project site 25-year 24-hour precipitation from the map and enter it in the appropriate field on the Project Location Tab. The computed scale factor will be displayed in the Scale Factor field.

Precipitation Input Selection Example
A project site is located in Grays Harbor County as shown in Figure 4.3. The project is located outside of the region where extended precipitation timeseries are available and the simple scaling approach must be used. The project site is located in the Clearwater precipitation region. The 25-year 24-hour precipitation at the Project Site is 6.0 inches. The Clearwater gage should be selected as the source for this project, and a project site 25-year, 24-hour precipitation of 6.0 inches should be entered in the appropriate field on the Project Location tab. The Scale factor would be computed by the program as the ratio of the project site to station 25-year, 24-hour precipitation, or 6.0 inches divided by 7.9 inches equals 0.759. This value would be displayed in the *Scale Factor* field and all precipitation values subsequently read by the program would be multiplied by this value.

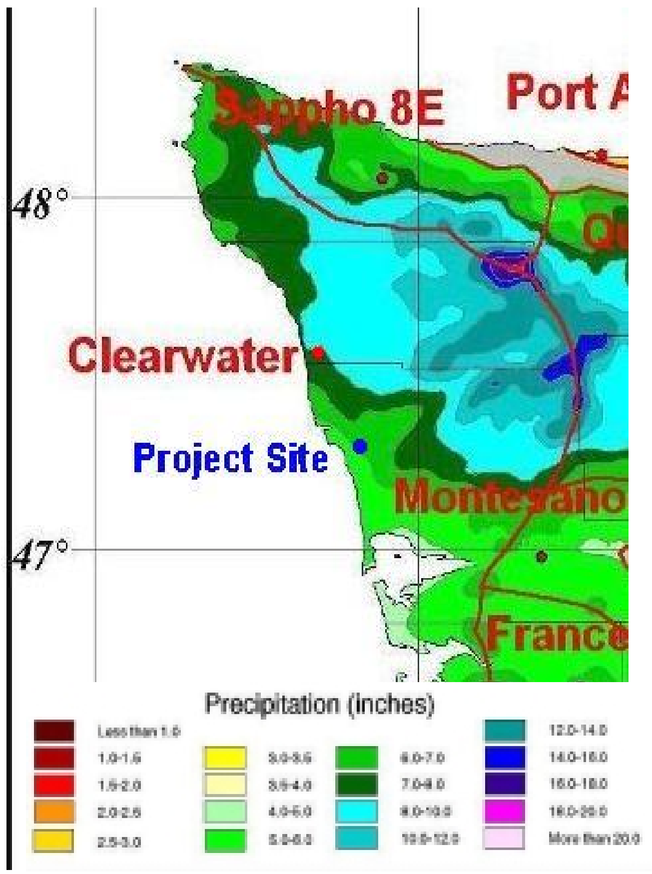

Figure 4.3 – Precipitation Input Selection Example for Project Sites Located Outside of Extended Precipitation Timeseries Region

5 Subbasin, Land Use, and Node Connection Input

To facilitate rainfall-runoff modeling, the project watershed must be defined in terms of subbasins, and the stream network within the watershed is described by a series of node connections (Figure 5.1). Land cover and soil type can vary within a subbasin and the program conducts rainfall-runoff modeling for each land cover/soil type combination separately. Nodes are used to collect runoff from the tributary area for a given subbasin and from the nodes of upstream subbasins. There is no attenuation of flow from subbasins to nodes and from one node to the next node as the hydrographs from the subbasins are translated directly to the receiving node without hydraulic routing.

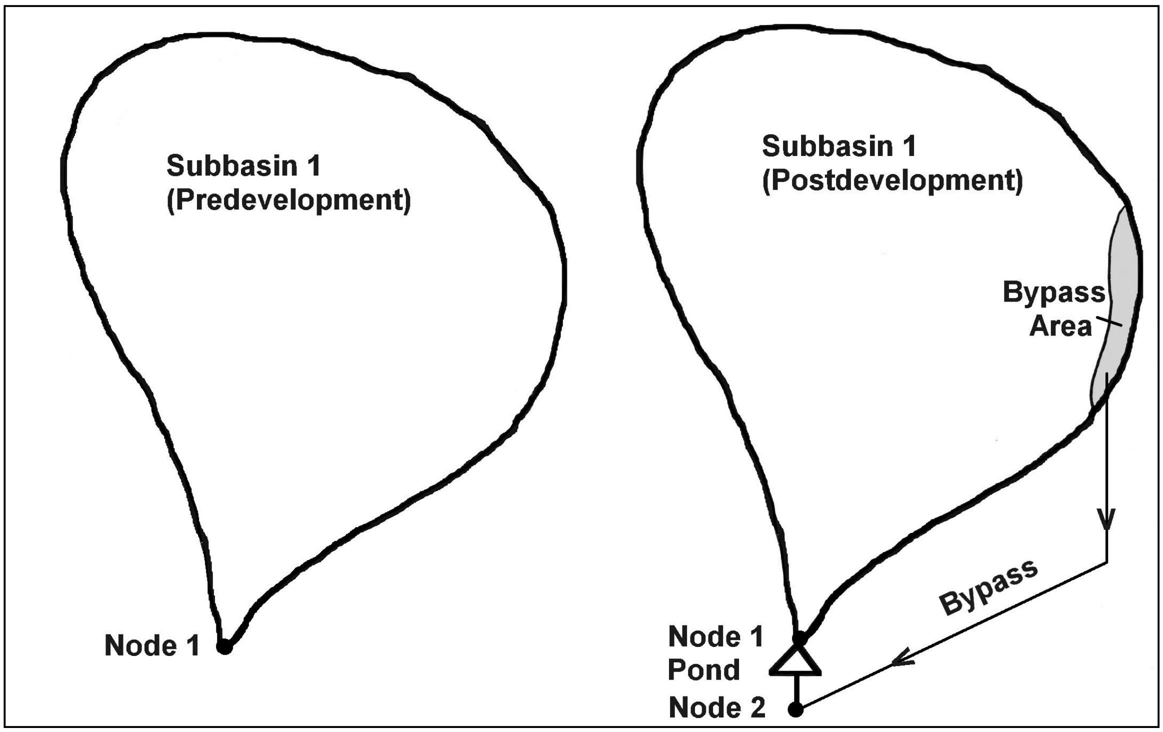

Figure 5.1 – Subbasin and Node Delineation, Single Subbasin with Bypass

5.1 Subbasin Land Use Input

The project tributary area can be divided into a maximum of six subbasins. The total acreage of each predeveloped and postdeveloped land cover/soil type combination (PERLNDs) is entered for each subbasin. A tributary node number is then chosen and all of the computed runoff from the subbasin is collected at this node.

Mapping of soil types by the Soil Conservation Service (SCS) is the most common source of soil/geologic information used in hydrologic analyses for stormwater facility design. Each soil type defined by the SCS has been classified into one of four hydrologic soil groups; A, B, C, and D. The *Stormwater Management Manual for Western Washington*[9] relates SCS hydrologic soil groups to HSPF soil/geologic groups as shown in Table 5.1

Table 5.1 – Relationship between SCS and HSPF Soil Groups

SCS Hydrologic Soil Group	MGSFlood/HSPF Soil/Geologic Group
A/B	Outwash
C	Till
D	Wetland

5.2 By-pass Areas

Local topographic constraints often make it impractical to direct all runoff from developed areas to a detention facility. If a portion of the developed watershed bypasses the tributary node, then a secondary by-pass node can be specified (Node 2 in Figure 5.1). This feature is useful for allowing a portion of the developed site to bypass the stormwater detention pond and the downstream node is used as the point of compliance. Acreage for each cover/soil type combination that bypasses the collection node is specified and runoff from this part of the development is collected at a user-specified by-pass node.

5.3 Node Connections

Node connections allow the user to connect runoff from multiple subbasins at a single point or connect bypass flows to a location downstream of the stormwater pond. In the example shown in Figure 5.2, Subbasins 1, 2, and 3 are connected to Nodes 1, 2, and 3 respectively, which represent the runoff from each subbasin. The runoff from each subbasin is combined at Node 4. Two acres of Subbasin 3 bypasses the pond to Node 5. Runoff from Node 4 will be used as input for sizing the stormwater detention pond with Node 5 used to save routed flows from the pond. The bypassed flows from Subbasin 3 will be added to the pond outflow during routing, and Node 5 will be the point of compliance. Following routing computations, flows stored at Node 5 will be the sum of the routed flows and the bypassed flows from Subbasin 3.

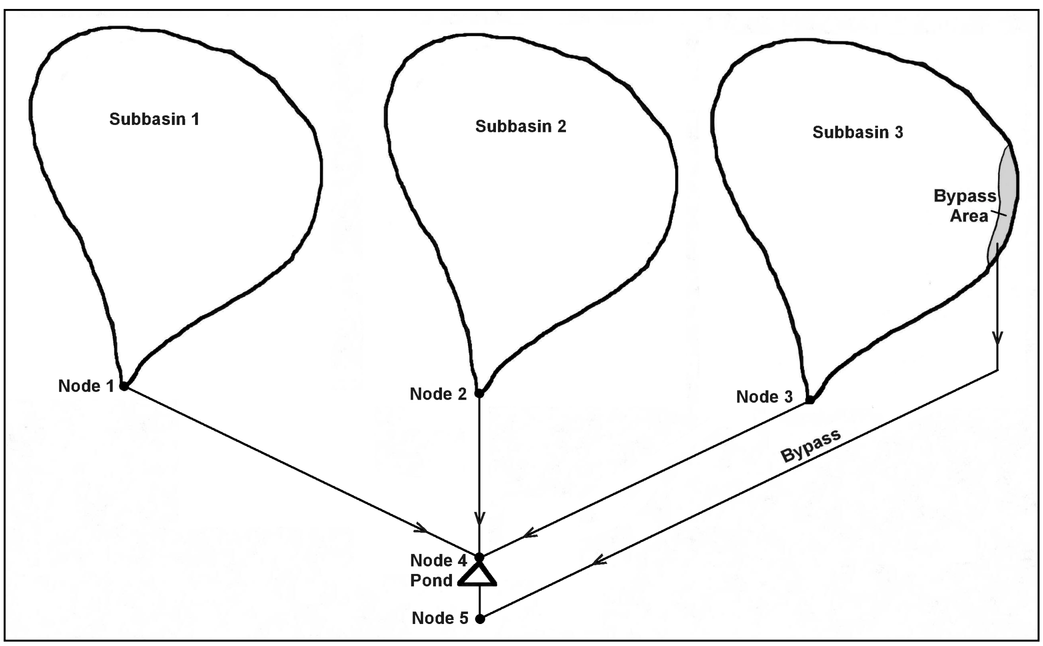

Figure 5.2 – Subbasin and Node Delineation, Multiple Subbasin Example with Bypass

6 Runoff Computation

MGSFlood computes runoff using the impervious (IMPLND) and pervious (PERLND) land segment subroutines from the HSPF model. Hourly precipitation and evaporation are read from the MGSRegion.mdb file, runoff is computed for predevelopment and postdevelopment conditions, and saved to a FORTRAN, binary, direct access file called TimeseriesStore.da. Runoff computations are performed on a *water year* basis, that is, they begin on October 1 and end on September 30. This is done because the soils are typically driest at the beginning of fall and a single set of antecedent conditions can be used for all regions of western Washington upon startup for the first year of the timeseries. The user can define a time period shorter than the full record for the runoff computations, although the full period of record should be used in facility design to provide the most accurate design.

The same FORTRAN direct access file is overwritten for each project analyzed by the flood model, i.e. the computed runoff timeseries are not saved for each project. Thus, the runoff must be recomputed before performing any pond design iterations to ensure that the TimeseriesStore.da file is up-to-date and contains runoff for the project currently under consideration.

6.1 Saving Runoff Timeseries from Selected Nodes

The *Runoff Computation* tab includes input fields for specifying which nodes runoff is to be saved. This feature allows the user to only save runoff from locations of interest in the project, thus reducing the amount of required disk storage.

The node representing the pond inflow must always be saved. If a portion of the site bypasses the pond, then the node representing the bypassed flows must also be saved if they are to be added to the pond outflow. Other nodes may be saved if flow statistics or hydrographs are desired at those locations.

6.2 Runoff Computation Timestep

In general, a one-hour timestep should be used for stormwater pond design while a 15-minute timestep provides better accuracy when peak flow computation is of interest for conveyance and design of some water quality treatment facilities. Currently, runoff can only be computed at a one-hour timestep.

7 Detention Pond Routing

7.1 Pond Hydraulics Data Input

Pond geometry and outlet works hydraulics are input to the program using a stage-volume-discharge rating table. The pond storage (acre-feet), surface area (acres), discharge (cfs), and infiltration (inches per hour) are computed by the user and entered in the table on the Pond Design tab. Information can be copied from an external spreadsheet program and pasted into the input table using the Windows Clipboard utility.

7.2 Pond Inflow and Outflow Node Definition

The nodes that discharge to and from the stormwater pond are defined on the *Pond Design* tab. Runoff saved from selected nodes during the runoff computation are available for input during routing. Runoff saved from the *Pond Inflow Node* will be used as inflow to the pond and routed flows will be added to the *Pond Outflow Node*. If a bypass flow node is present, it should be selected as the Pond Outflow Node. If no bypassed flows are present, then Pond Outflow Node should be used. The Pond Outflow Node is a default node that holds the pond discharge timeseries if no other nodes are tributary to the pond outflow.

7.3 Governing Equations for Pond Routing

Detention pond routing is performed using a Modified Puls routing routine developed by the US Army Corps of Engineers for the HEC-1[25] flood hydrograph package. A storage indication function is computed from given storage and outflow data (Equation 7.1).

$$STRI(I) = C * \frac{STOR(I)}{\Delta t} + \frac{OUTFL(I)}{2} \qquad (7.1)$$

Where: *STRI* is the storage indication in cfs, *STOR* is the storage for a given outflow in acre-ft, *OUTFL* is the outflow in cfs, *C* is the conversion factor from acre-ft/hour to cfs, Δt is the timestep in hours, and *I* is a subscript indicating corresponding values of storage and outflow.

Storage indication at the end of each time interval is given by:

$$STR(2)=STRI(1)+QIN-Q(1) \qquad (7.2)$$

Where: *QIN* is the average inflow in cfs, and *Q* is the outflow in cfs, and subscripts 1 and 2 indicate beginning and end of the current timestep.

The outflow at the end of the time interval is interpolated from a table of storage indication versus outflow. Storage is then computed from:

$$STR = \left(STRI - \frac{Q}{2} \right) * \frac{\Delta t}{C} \qquad (7.3)$$

8 Flow Frequency and Duration Statistics

MGSFlood contains routines for computing flood-frequency and flow duration statistics on streamflow timeseries computed by the program. The following sections describe the flow duration and flow frequency statistics, and the flow duration pond design criteria as required by the Washington State Department of Ecology[9].

8.1 Flow Duration Statistics

Flow duration statistics provide a convenient tool for characterizing streamflow computed with a continuous hydrologic model. Duration statistics are computed by tracking the fraction of time that a specified flow rate is equaled or exceeded. The program does this by dividing the range of flows simulated into discrete increments and then tracks the fraction of time that each flow is equaled or exceeded. For example, Figure 8.1a shows a one-year flow timeseries computed at hourly timesteps from a ten acre forested site and Figure 8.1b shows the flow duration curve computed from this timeseries.

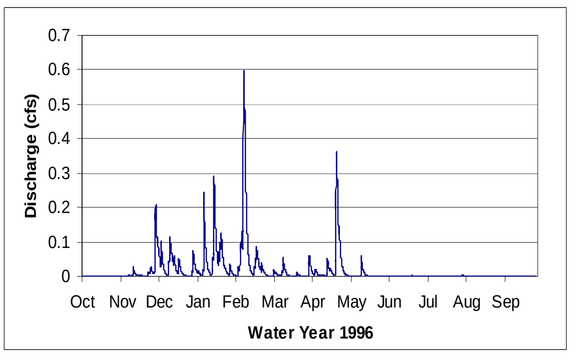

Figure 8.1a – Runoff from 10-Ac Forested Site

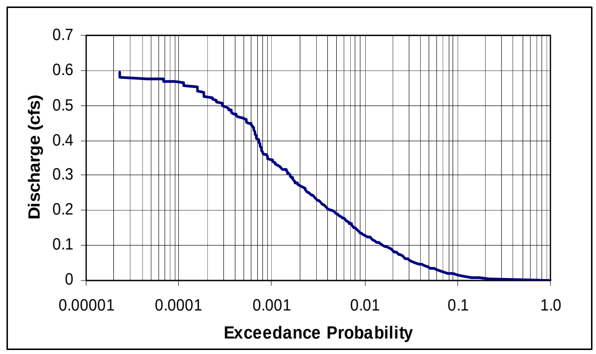

Figure 8.1b – Flow Duration Curve Computed Using Timeseries in Figure 8.1a

The fraction of time that a particular flow is equaled or exceeded is called *exceedance probability*. It should be noted that exceedance probability for duration statistics is different from the *annual exceedance probability* associated with flood frequency statistics and there is no practical way of converting/relating annual exceedance probability statistics to flow duration statistics.

8.2 Flood-Frequency Analysis and Statistics

Flood-frequency analysis seeks to determine the flood flow with a probability (*p*) of being equaled or exceeded in any given year. Return period (*Tr*) or recurrence interval is often used in lieu of probability to describe the frequency of exceedance of a flood of a given magnitude. Return period and annual exceedance probability are reciprocals (Equation 8.1) and the two are used interchangeably in this section. Flood-frequency analysis is most commonly conducted for flood peak discharge but can also be computed for maximum or minimum discharges for various durations. Flood-frequency analysis as used here refers to analysis of flood peak discharge.

$$Tr = \frac{1}{p} \qquad 8.1$$

Where:

Tr is the average recurrence interval in years, and
p is the annual exceedance probability.

For flows that have not been routed through a stormwater pond, MGSFlood fits the Generalized Extreme Value[14] probability distribution to the annual maxima peak flows using L-Moment[14] statistics. Flow magnitudes for recurrence intervals ranging from 6-months to 500-years are computed with this distribution.

The exceedance probability for streamflow that has been routed through the stormwater pond are estimated using the Gringorten[12] plotting position formula (Equation 8.2), which is a non-parametric approach. An example probability plot comparing forested land use with the pond outflow is shown in Figure 8.2.

$$Tr = \frac{N + 0.12}{i - 0.44} \qquad 8.2$$

Where: *Tr* is the recurrence interval of the peak flow in years,
i is the rank of the annual maxima peak flow, ranked from highest to lowest, and
and *N* is the total number of years simulated.

A probability distribution, such as the Generalized Extreme Value or Log-Pearson III[15], is not used for estimating the frequency characteristics of discharges from the pond because these and other three-parameter distributions typically do a very poor job of fitting annual maxima flows regulated by stormwater ponds and can produce grossly inaccurate estimates of the flow for rare recurrence intervals.

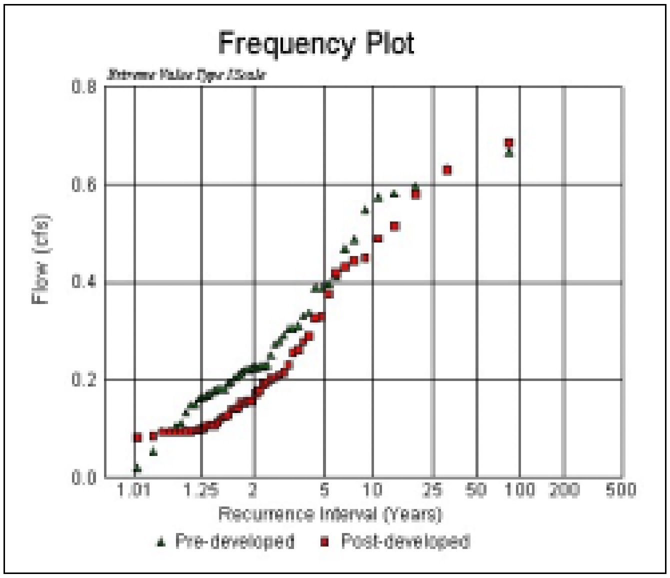

Figure 8.2 – Example Probability Plot Comparing Pond Outflow (Postdeveloped) with Predeveloped

9 Pond Design to Flow Duration Standard

In the past, stormwater pond design criteria have focused on flood control by regulating peak flow rates. Even if the design goal for controlling peak discharge is successful, the aggregate duration that flows occupy the stream channels is greater than under predeveloped conditions because the overall runoff volume is greater under postdevelopment conditions. This increased runoff volume results in increased erosive work being done on the receiving channels, and results in streams that are incised and devoid of the characteristics needed to support fish habitat.

The *flow duration standard* seeks to maintain predevelopment levels of the magnitude and duration of streamflow for those streamflows that exceed the threshold for bedload movement. The threshold for bedload movement is assumed to be 50-percent of the 2-year flow computed for predevelopment conditions[16,2]. The intent of this standard is to prevent increases in the rate of stream channel erosion over that which occurs under predeveloped conditions.

9.1 Flow Duration Standard

The following is the flow duration standard required by the Department of Ecology *Stormwater Management Manual for Western Washington*[9]:

Stormwater discharges shall match developed discharge duration to predeveloped durations for the range of predeveloped discharge rates from 50-percent of the 2-year peak flow up to the full 50-year peak flow.

The pre-developed condition to be matched shall be a forested land cover unless reasonable, historic information is provided that indicates the site was prairie prior to settlement (modeled as pasture). This standard requirement is waived for sites that will reliably infiltrate all the runoff from impervious surfaces and converted pervious surfaces.

The flow duration standard can be viewed graphically as shown in Figure 9.1. The flow duration curve for the site under predeveloped conditions (forested land cover in this example) is computed and is the target to which the postdeveloped flow duration curve is compared. The flow duration curve for the pond discharge must match the predeveloped curve between ½ of the predeveloped 2-year (1/2 Q2) and the predeveloped 50-year (Q50). The postdeveloped curve must match the predeveloped within the tolerance levels specified in Table 9.1 and shown graphically in Figure 9.2.

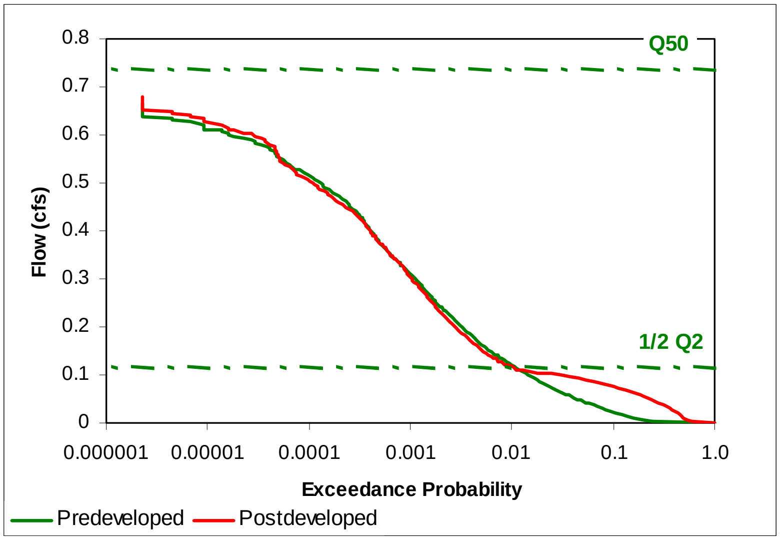

Figure 9.1 – Comparison of Predeveloped and Postdeveloped Flow Duration Curves

Table 9.1 – Tolerance Criteria for Matching Postdevelopment Flow Duration Curves to Predevelopment Levels
1. The exceedance probability of postdeveloped flow duration values must not exceed the predeveloped values between ½ of the 2-year and the 2-year discharge.
2. The exceedance probability of postdevelopment flow duration values must not exceed the predeveloped exceedance probability by more than 10% between the 2-year and 50-year discharge.
3. No more than 50-percent of the postdeveloped flow duration values can be greater than the predeveloped values between ½ Q2 and Q50.

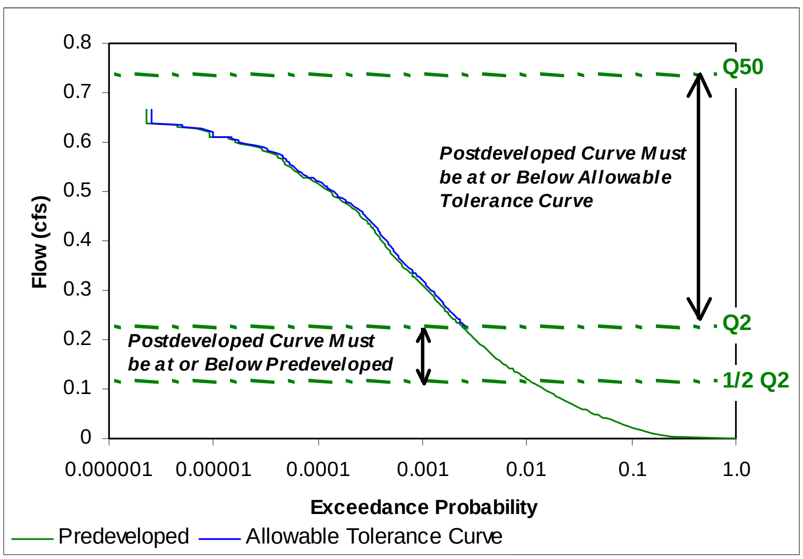

Figure 9.2 – Criteria for Matching Postdevelopment (Pond Outflow) Duration Curve to Predevelopment Flow Duration Curve

In the example shown in Figure 9.3, Tolerance Criterion 1 is met because the postdeveloped flow duration curve is at or below the predeveloped between ½ of the 2-year and the 2-year. Tolerance Criterion 2 is not met, because postdeveloped flow duration curve exceeds the tolerance curve above 0.45 cfs. Tolerance Criterion 3 is met because more than 50-percent of the postdeveloped duration values are at or below the predeveloped curve. Because not all three of the criteria are met, the pond does not meet the flow duration standard and modifications would be needed to the pond size and/or outlet works to meet the standard.

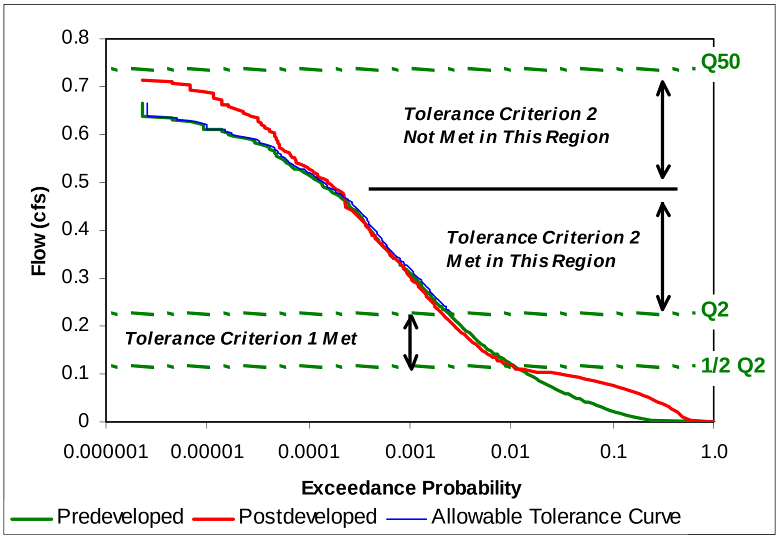

Figure 9.3 – Predevelopment and Postdevelopment (Pond Outflow) Flow Duration Curves and Flow Duration Standard Performance Criteria
(Pond Fails Criterion 2, and Does not Meet Flow Duration Standard)

9.2 Pond Design Procedure

The procedure for designing a stormwater pond to meet the flow duration standard discussed in Section 9.1 is described in the following sections.

9.2.1 Pond Design Procedure

Designing a pond to meet the flow duration standard is a trial and error process whereby the pond hydraulic rating table is input to the program, routing is performed, and the performance is plotted. The design steps are as follows:

Step 1. Input land use and compute runoff.

Step 2. Compute flow statistics for predevelopment land use. From the *Tools* tab, select the pond inflow node to compute statistics and click the *Run* button. View the output report from the File/View Report menu or click the report button from the tool bar. Note the predeveloped 2-year and 50-year flows.

Step 3. Determine an initial storage volume.

Step 4. Develop a pond-rating table consisting of elevation, pond surface area, volume and discharge using a spreadsheet or other hydraulics program. Size the lower orifice such that it passes ½ of the predevelopment 2-year discharge at a head equal to 50 to 70 percent of the pond depth. Use a lower head (closer to the 50-percent value) if the site has a relatively low percentage of effective impervious surface (less than 40-percent) and/or is located in a relatively dry area of western Washington (mean annual precipitation less than 35 inches). Use higher head if the site has a relatively high percentage of effective impervious surface and/or is located in an area of western Washington with relatively high mean annual precipitation.

Step 5. Locate the upper orifice at an elevation corresponding to the head used to size the lower orifice. Size the upper orifice such that the combined discharge of the upper and lower orifices equals the 50-year predeveloped flow.

Step 6. Enter the rating table or use the Windows clipboard utility to copy and paste the data in the *Pond Hydraulic Routing Table* on the *Pond Design* tab.

Step 7. Click the *Route Flows* button with the *Compute Stats Plot Performance* box checked. The program will plot the duration statistics for the pond outflow and predevelopment condition, and compute whether or not the pond meets all the criteria of the flow duration standard.

Step 8. If any of the criteria are not met, then the pond configuration must be modified, the rating table recomputed, and the process repeated. Guidelines for adjusting the pond size and outlet works are discussed in the following section.

9.2.2 Guidelines for Adjusting Pond Performance

General guidance for adjusting the geometry and outlet works of stormwater ponds to meet the duration standard were developed by King County[16] and are summarized in Figure 9.6 and described below. Refinements should be made in small increments with one refinement at a time.

1. *Bottom Orifice Size* – Adjust the bottom orifice to control the lowest arc of the postdeveloped flow duration curve. Increase the orifice size to raise the arc, decrease it to lower the arc.

2. *Height of Second Orifice* – The invert elevation of the second orifice affects the point on the flow duration curve where the transition (break in slope) occurs from the curve produced by the low-level orifice. Lower the invert elevation of the second orifice to move the transition point to the right on the lower arc. Raise the height of the second orifice to move the transition point to the left on the lower arc.

3. *Second Orifice Size* – Adjust to control the arc of the curve for postdeveloped conditions. Increase the size to raise the arc, decrease it to lower the arc.

4. *Pond Volume* – Adjust the pond volume to control the upper end of the duration curve. Increase the volume to prevent overflow, decrease the volume if the duration curve is substantially below the overflow level.

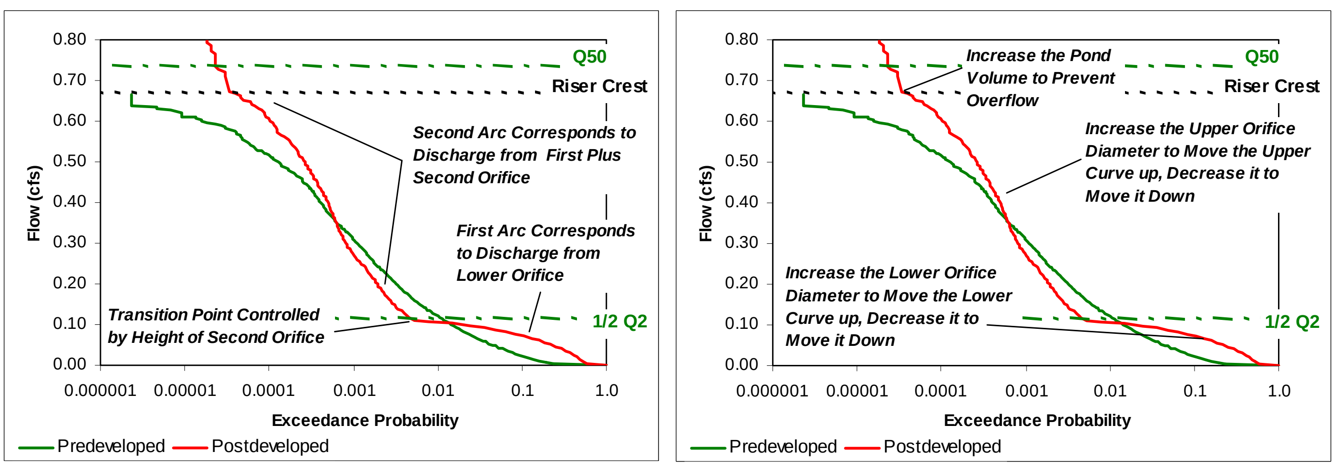

Figure 9.6 – General Guidance for Adjusting Pond Performance

- Analyze the duration curve from bottom to top, and adjust orifices from bottom to top.

- The bottom arc corresponds with the discharge from the bottom orifice. Reducing the bottom orifice discharge lowers and shortens the bottom arc while increasing the bottom orifice raises and lengthens the bottom arc.

- Inflection points in the outflow duration curve occur when additional structures (orifices, notches, overflows) become active.

- Lowering the upper orifice moves the transition right on the lower arc and raising the upper orifice moves the breakpoint left of the lower arc

- The upper arc represents the combined discharge of both orifices. Adjustments are made to the second orifice as described above for the bottom orifice.

- Increasing the facility volume moves the entire curve down and to the left. This is done to control riser overflow conditions. Decreasing facility volume moves the entire curve up and to the right. This is done to ensure that the outflow duration curve extends up to riser overflow.

10 Project Documentation/Reporting

The project reporting utility creates a report that documents all model inputs, stormwater pond design information, and frequency and duration statistics. The report is created and viewed on screen by selecting *View Report* from the *File* menu or from the *View Report* icon ( ) on the tool bar. Note that the View Report utility only becomes active after saving the project file for the first time. The report can be printed by selecting *Print Report* from the File menu. When the project report is printed, any frequency and duration graph images stored in the project directory are also printed. These images represent the latest graphs plotted from the *Graphs* tab. Each time the report is viewed or printed, a copy of the report is stored in a file with the name *<ProjectName.rtf>* in the project data directory. This file can be viewed with a text editor or imported into word processor or spreadsheet program. A partial listing of a project report is shown below.

Figure 10.1 – Project Report Output (Partial Listing)

```
*******************************************************************************
                                             MGS FLOOD
                                          PROJECT REPORT


Program Version: 2.0.0                           Run Date: 04/30/2002 5:07 PM
*******************************************************************************

Input File Name: Test7.fld
Project Name  :  SR900 Road Expansion
Analysis Title:  Flow Duration Analysis
Comments      :  Test Reporting

Precipitation Station Data Selected
Climatic Region Number: 1
Precipitation Station : 457488    SeaTac                     10/01/1948-10/01/1998
Evaporation Station   : 456803    Puyallup
At Site 25-Year, 24-Hour Precipitation  (inches): 3.31
Gage 25-Year, 24-Hour Precipitation  (inches)   : 3.31
Precipitation Scale Factor : 1.000
Evaporation Scale Factor   : 0.750

HSPF Parameter Region Number: 1
HSPF Parameter Region Name  : USGS Default

********** Default HSPF Parameters Used (Not Modified by User) ***************
```

```
********** Watershed Definition **********
Number of Subbasins:  1


 ********** Subbasin Number: 1 **********
 ***Tributary to Node: 1
 ***Bypass to Node   : None
                ---------Area(Acres) -------------
                              ------Developed-----
                Predeveloped  To Node  Bypass Node  Include GW
Till Forest        10.000      0.000         0.000     No
Till Pasture       0.000       0.000         0.000     No
Till Grass         0.000       0.000         0.000     No
Outwash Forest     0.000       0.000         0.000     No
Outwash Pasture    0.000       0.000         0.000     No
Outwash Grass      0.000       0.000         0.000     No
Wetland            0.000       0.000         0.000     No
Impervious         0.000       10.000        0.000
SUBBASIN TOTAL     10.000      10.000        0.000

 *** Subbasin Connection Summary ***
Subbasin 1 --------------> Node 1

 *** By-Pass Area Connection Summary ***
No By-Passed Areas in Watershed

Pond Inflow Node : 1
Pond Outflow Node: 99

\
********** Retention/Detention Facility Summary **********

User Defined Routing Table Used

WSEL (ft) at Start of Simulation:  0
Elev(ft)   Area(ac) Vol(ac-ft) Disch(cfs) Infilt(cfs)
   100.00   0.000     0.000     0.000       0.000
   100.12   1.867     0.224     0.027       0.000
   100.18   1.872     0.337     0.033       0.000
   100.30   1.877     0.563     0.043       0.000
   100.36   1.881     0.677     0.047       0.000
   100.42   1.883     0.791     0.051       0.000
   100.48   1.885     0.905     0.055       0.000
   100.54   1.889     1.020     0.058       0.000
   100.60   1.892     1.135     0.061       0.000
   100.66   1.894     1.250     0.064       0.000
   100.78   1.899     1.481     0.069       0.000
   100.90   1.904     1.714     0.075       0.000
   100.96   1.907     1.831     0.077       0.000
   101.08   1.913     2.066     0.082       0.000
   101.14   1.916     2.184     0.084       0.000
   101.20   1.918     2.302     0.086       0.000
   101.26   1.921     2.420     0.088       0.000
   101.38   1.926     2.658     0.092       0.000
   101.44   1.929     2.778     0.094       0.000
   101.50   1.931     2.897     0.096       0.000
```

101.56	1.935	3.018	0.098	0.000
101.62	1.937	3.138	0.100	0.000
101.68	1.940	3.259	0.102	0.000
101.80	1.945	3.501	0.106	0.000
101.86	1.948	3.623	0.107	0.000
101.92	1.951	3.745	0.109	0.000
101.94	1.952	3.786	0.110	0.000
102.00	1.955	3.909	0.121	0.000
102.03	1.956	3.970	0.129	0.000
102.06	1.957	4.032	0.139	0.000
102.12	1.960	4.155	0.159	0.000
102.24	1.965	4.402	0.209	0.000
102.30	1.968	4.526	0.240	0.000
102.42	1.974	4.776	0.308	0.000
102.48	1.976	4.901	0.345	0.000
102.54	1.979	5.026	0.385	0.000
102.60	1.982	5.152	0.426	0.000
102.66	1.984	5.278	0.469	0.000
102.72	1.987	5.405	0.514	0.000
102.78	1.990	5.532	0.561	0.000
102.84	1.993	5.659	0.609	0.000
102.90	1.996	5.787	0.659	0.000
102.96	1.998	5.914	0.710	0.000
103.00	2.000	6.000	0.745	0.000
103.03	2.001	6.064	0.851	0.000
103.09	2.004	6.193	1.236	0.000
103.18	2.008	6.386	2.060	0.000
103.30	2.014	6.645	3.417	0.000
103.42	2.019	6.906	4.827	0.000
103.54	2.025	7.168	5.972	0.000

.
.
.

```
**** Flow Duration Performance According to Dept. of Ecology Criteria ****
Excursion at Predeveloped ½Q2 (Must be Less Than 0%):           -24.7%    PASS
Maximum Excursion from ½Q2 to Q2 (Must be Less Than 0%):        -24.5%    PASS
Maximum Excursion from Q2 to Q50 (Must be less than 10%):       6.0%      PASS
Percent Excursion from Q2 to Q50 (Must be less than 50%):       3.8%      PASS

****************************************************************
* POND MEETS ALL DURATION DESIGN CRITERIA:                                PASS
****************************************************************
```

11 Exporting Runoff Timeseries

Runoff timeseries computed by the program are stored in a binary direct access file. These timeseries can be exported to an ASCII formatted file from the *Tools* tab. The output frequency option defines the number of time intervals to be aggregated before output is written to the file. For example, if the *Daily* option button is selected, then runoff will be aggregated and saved to the file once per day. For runoff computed on an hourly time-step, 24 values will be aggregated according to the option selected in the *Display* box. If *Maximum* were selected, then the maximum daily flow would be output, *Minimum* would result in the minimum daily flow, and *Average* would result in the average daily flow.

The output file format consists of the end of period date and time followed by the pre and post developed flows at each node and the pond outflow and water surface elevation (Figure 11.1).

Figure 11.1 – Example Output Produced by Export Utility

```
      Date            Node 1(cfs)                   Pond Routing Data
                      Predev         PostDev          PondQ (cfs)    WSEL (ft)
10/02/1948 00:00    0.0000E+00     0.0000E+00     0.0000E+00     1.0000E+02
10/03/1948 00:00    0.0000E+00     0.0000E+00     0.0000E+00     1.0000E+02
10/04/1948 00:00    2.8709E-05     6.2104E-01     1.7623E-02     1.0008E+02
10/05/1948 00:00    8.9352E-05     4.2463E-01     3.1080E-02     1.0016E+02
10/06/1948 00:00    1.2052E-05     7.6888E-03     3.0735E-02     1.0016E+02
```

etc…

12 References

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PART II – PROGRAM OPERATION AND DATA INPUT

1 Purpose

MGS Flood is a general, continuous, rainfall runoff computer model developed for stormwater facility design in western Washington. Specifically, the program is intended to size stormwater detention ponds to meet the requirements of the 2001 Washington State Department of Ecology Stormwater Management Manual for Western Washington[9]. The program uses the Hydrological Simulation Program-Fortran (HSPF)[26] routine for computing runoff from rainfall.

The program was intended for the analysis of stormwater detention facilities and should not be used for conveyance design unless the conveyance system is downstream of a stormwater pond. The program is applicable to lowland watersheds smaller than about 320 acres where snowmelt is not a significant contributor to floods or to the annual runoff volume. Additional information on program applicability is described in Part I.

2 Computer Requirements

- Windows 9x/2000 with 300 MB uncompressed hard drive space.
- Pentium 3, 800 MHz or faster processor (desirable).
- The program is designed to be installed and operated from a single computer and not run from a network.

3 Detention Pond Sizing Overview

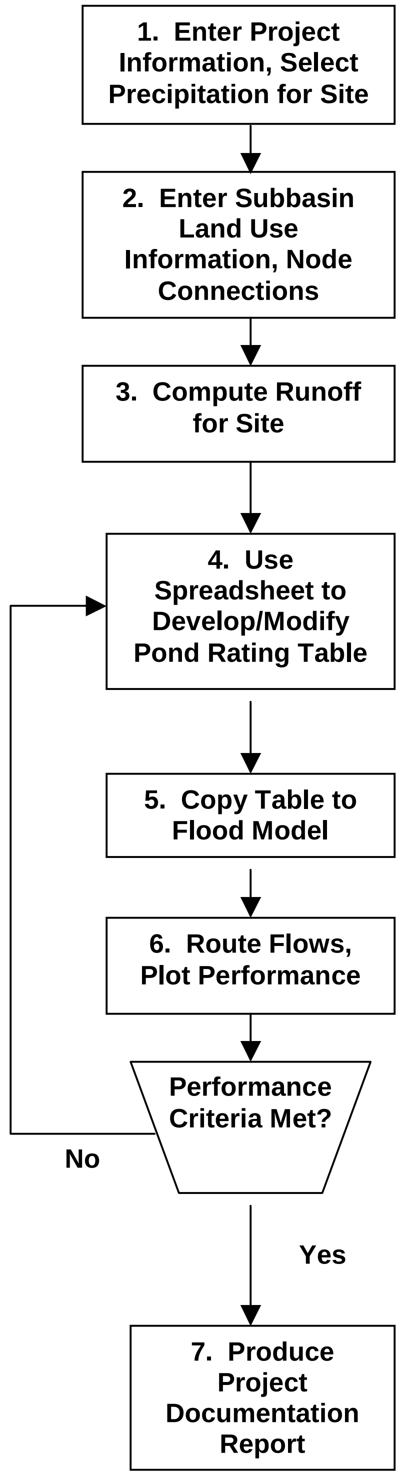
The input screen for MGS Flood (Figure 3.1) is organized as a series of tabs that follows the sequence of steps to analyze streamflow and design a stormwater pond. These steps include:

- Entering the project information and determining the precipitation and runoff parameters,
- Entering the subbasin land use information and node connections,
- Computing runoff,
- Sizing the stormwater pond,
- Computing streamflow statistics,
- Plotting pond performance graphs.

Figure 3.1 – MGSFlood Tabs at Bottom of Input Screen

A flow chart of the design process is shown in Figure 3.2.

Figure 3.2 - Stormwater Pond Design Procedure Using MGS Flood



4 Starting Program, Saving Data

MGSFlood is installed to a default folder called MGSFlood in the \Program Files directory. A shortcut created under the Start menu in the *Programs-MGSSoftware* folder can be used to start the program. When the program starts, the Graphics Server icon appears in the system tray at the bottom of the screen (Figure 4.1). Graphics Server is a graphics package used by MGSFlood to plot statistics and hydrographs and is installed with MGSFlood. When MGSFlood terminates, Graphics Server is unloaded from memory.

Figure 4.1 – Graphics Server Icon in System Tray

MGSFlood creates a number of files on disk for each project so it is recommended that a separate folder be created for each project. This can be accomplished automatically when saving the project for the first time. The program will prompt for the creation of a new folder with the project name (Figure 4.2). Responding yes to this prompt will create a new folder with the project file stored in it. All subsequent files created by the program for the project will be stored in this directory.

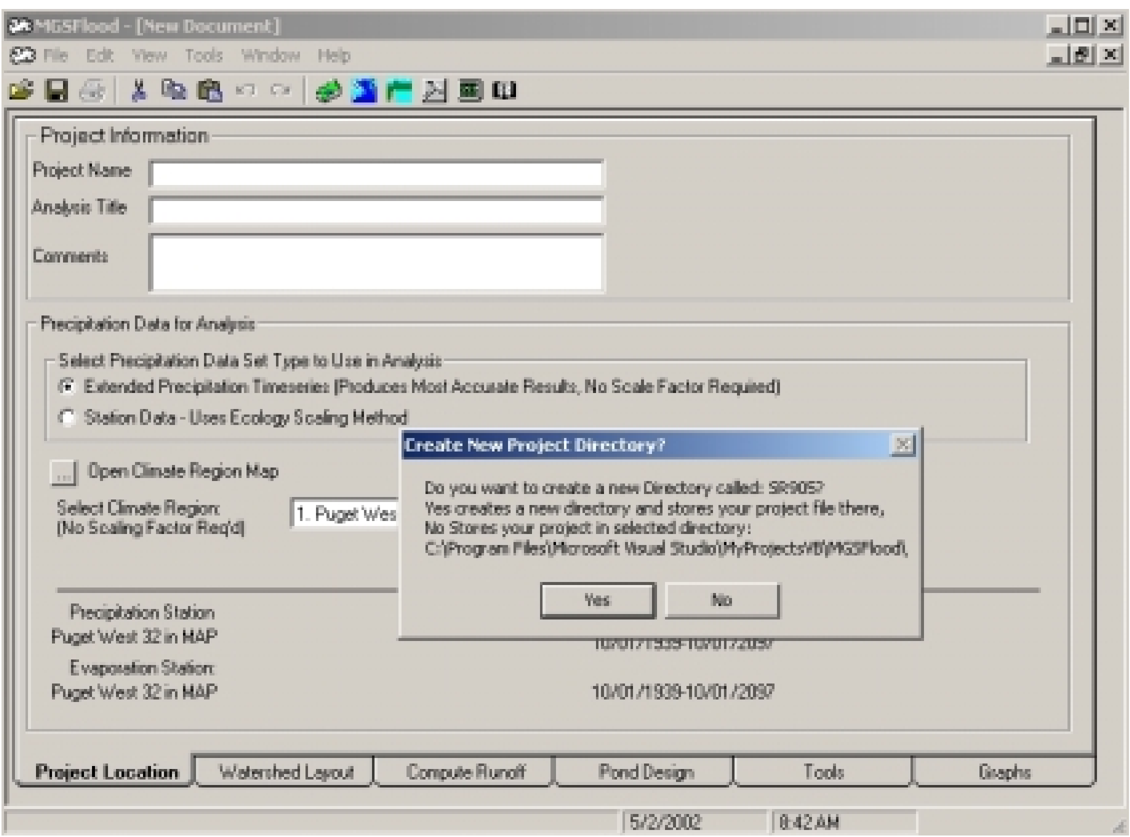


Figure 4.2 – Prompt to Create a new Project Folder when Saving a Project for the First Time

5 Getting Help

Context sensitive help is available by pressing F1 or by selecting Help from the command menu at the top of the screen.

6 Project Location Tab

The project location tab contains two different types of data; *Project Information* and *Precipitation Data Used in Analysis* (Figure 6.1). Data fields in the Project Information section are used for identifying the project. Information entered here is printed on the project reports.

The program contains two options for selecting precipitation input for project analysis; *Extended Precipitation Timeseries* and *Station Data*. The two options are discussed in the following sections.

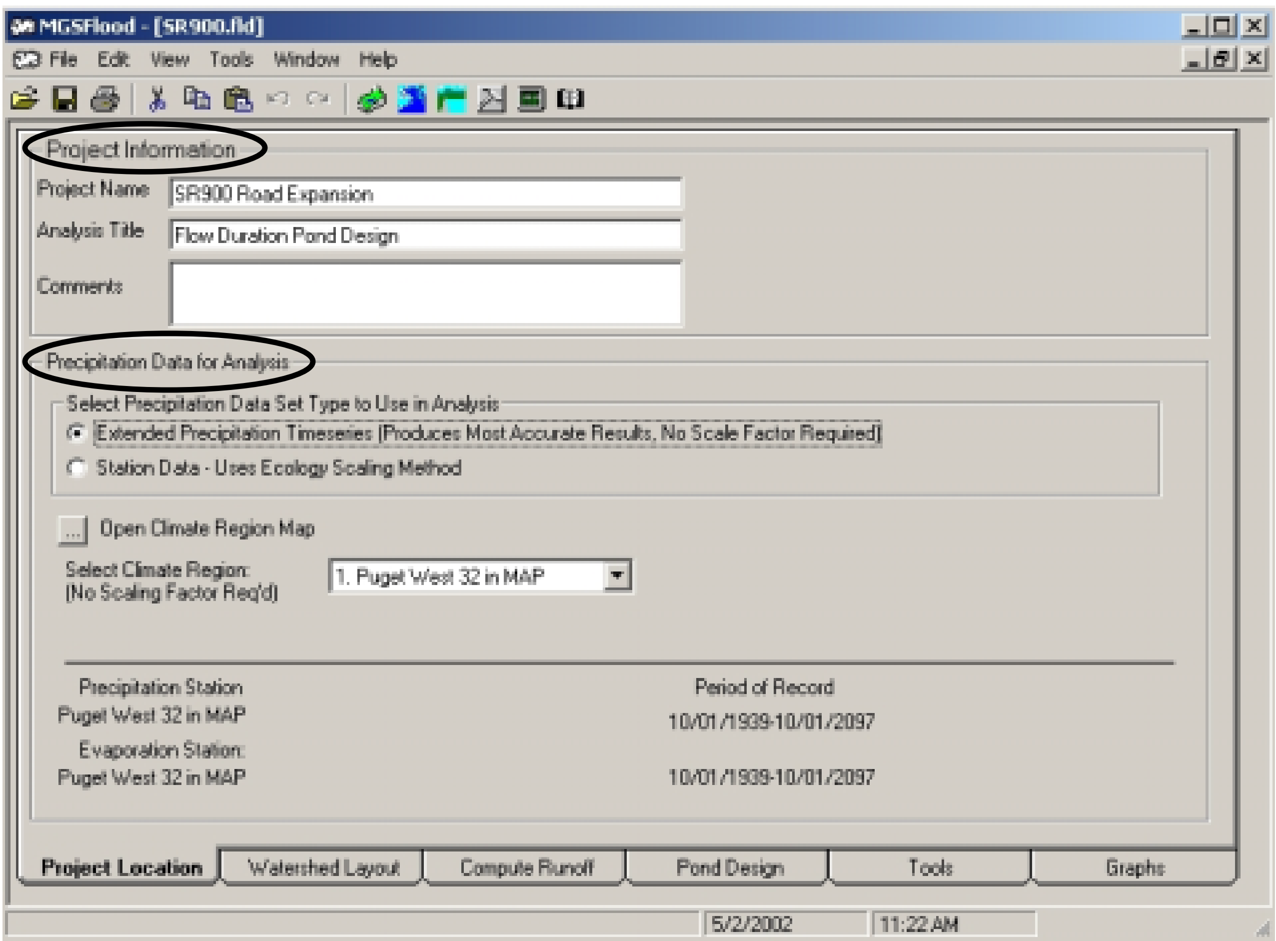


Figure 6.1 – Project Location Tab

6.1 Extended Precipitation Timeseries Selection

Extended Precipitation timeseries utilizes a family of pre-scaled precipitation and evaporation timeseries. These timeseries were developed by combining and scaling precipitation records from widely separated stations resulting in record lengths in excess of 100-years. Extended hourly precipitation and evaporation timeseries have been developed using this method for most of the lowland areas of western Washington where stormwater projects will be constructed. These timeseries should be used for facility design for projects located in the region shown in Figure 6.2.

To select the precipitation and evaporation input for a project, open the Precipitation Map from the Project Location Tab. Locate the project site on the map and note in the zone and the mean annual precipitation for the project site. From the Climatic Region drop down box on the *Project Location* tab, select the precipitation timeseries corresponding to the region and mean annual precipitation noted from the map. For project sites located in Pierce County, select the Pierce County precipitation timeseries corresponding to the region and mean annual precipitation for the project site.

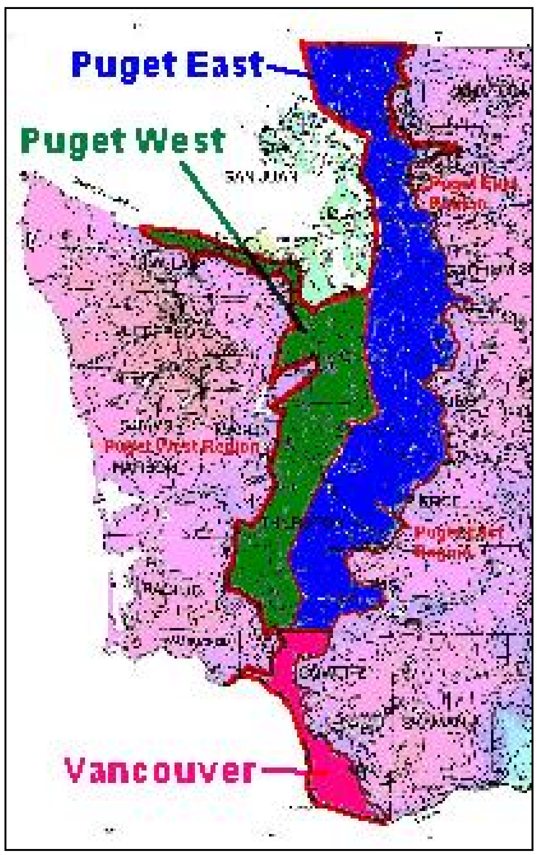


Figure 6.2 – Extended Precipitation Timeseries Regions

The example project site shown in Figure 6.3, is located in the western Puget Sound Region and the project mean annual precipitation is 51 inches. The precipitation timeseries for the western Puget Sound Region with mean annual precipitation closest to the project site should be selected from the drop down box. In this case, Puget Sound West Region, 52 inches MAP should be used.

Figure 6.3 – Extended Precipitation Timeseries Selection Example

6.2 Precipitation Station Selection

For projects sites located outside of the extended timeseries region, a *source* gage is selected and a single scaling factor is applied to transpose the hourly record to the site of interest (target site). The current approach for single factor scaling, as recommended in the *Stormwater Management Manual for Western Washington*[9], is to compute the scaling factor as the ratio of the 25-year 24-hour precipitation[21] for the target and source sites.

To select the precipitation and evaporation input for a project location outside the area where the extended precipitation timeseries apply, check the *Station Data* option button and open the Precipitation Map from the Project Location Tab. Choose the precipitation region where the project site is located. Read the project site 25-year 24-hour precipitation from the map and enter it in the appropriate field on the Project Location Tab. The computed scale factor will be displayed in the *Scale Factor* field.

For the example project site shown in Figure 6.4, the Clearwater gage should be selected as the source gage, and a project site 25-year, 24-hour precipitation of 6.0 inches should be entered in the appropriate field on the Project Location tab. The Scale factor would be computed by the program as the ratio of the project site to station 25-year, 24-hour precipitation, or 6.0 inches divided by 7.9 inches equals 0.759. This value would be displayed in the *Scale Factor* field and all precipitation values subsequently read by the program would be multiplied by this value.

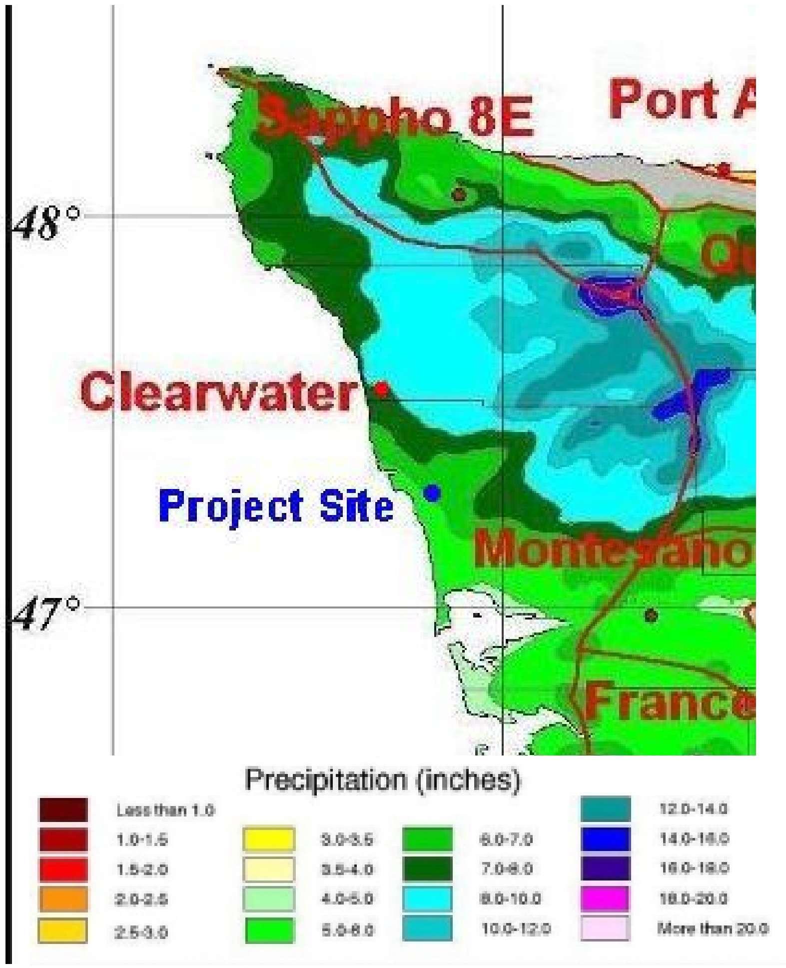


Figure 6.4 – Precipitation Input Selection Example for Project Sites Located Outside of Region Covered by Extended Timeseries

7 Watershed Layout Tab

Subbasin areas and how the subbasins are connected is defined on the Watershed Layout Tab.

7.1 Subbasin Areas

Clicking the *Subbasin Definitions* button displays the screen used for entering land use information for each subbasin (Figure 7.1). Up to six subbasins can be defined.

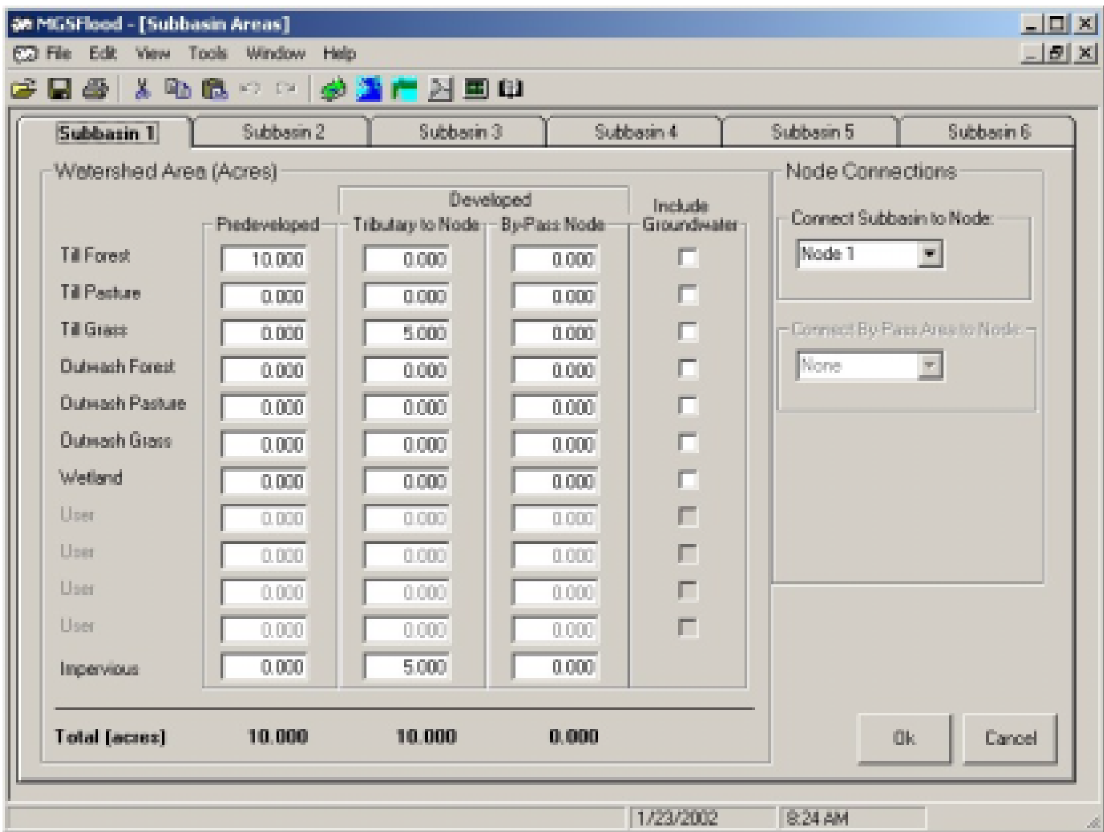


Figure 7.1 – Subbasin Area Definition Screen

7.1.1 Area Tributary to Pond

For each subbasin, land use is defined in acres for *Predeveloped* and *Developed* conditions. The developed conditions entry includes a column for the number of acres tributary to and the number of acres that bypass the node (Figure 7.1). The *Stormwater Management Manual for Western Washington*[9] relates SCS hydrologic soil groups to HSPF soil/geologic groups as shown in Table 7.1

Table 7.1 – Relationship between SCS and HSPF Soil Groups

SCS Hydrologic Soil Group	MGSFlood/HSPF Soil/Geologic Group
A/B	Outwash
C	Till
D	Wetland

7.1.2 Area Bypassing Pond

Local topographic constraints often make it impractical to direct all runoff from developed areas to a detention facility. The bypass feature allows an area of the subbasin to be connected downstream of the stormwater pond as shown in Figure 7.2. Node 2 becomes the point of compliance for the pond meaning that the postdevelopment flows at Node 2 would have to be controlled to the predeveloped level computed at Node 1.

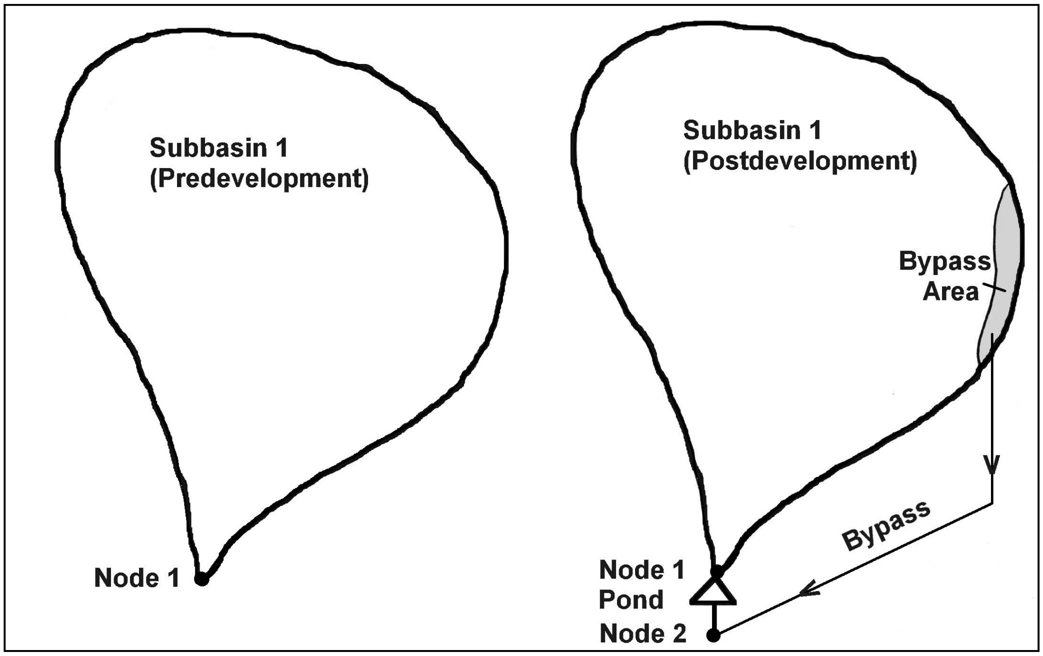


Figure 7.2 – Subbasin and Node Delineation, Single Subbasin with Bypass

7.1.3 Node Connections

Node connections allow the user to connect runoff from multiple subbasins to a single point or connect bypass flows to a location downstream of the stormwater pond. In the example shown in Figure 7.3, Subbasins 1, 2 and 3 are connected to Nodes 1, 2, and 3 respectively which represent the runoff from each subbasin. The runoff from each subbasin is combined at Node 4. A portion of Subbasin 3 bypasses the pond to Node 5.

Runoff from Node 4 will be used as input for sizing the stormwater detention pond with Node 5 used to save routed flows from the pond. The bypassed flows from Subbasin 3 will be added to the pond outflow during routing, and Node 5 will be the point of compliance. Following routing computations, flows stored at Node 5 will be the sum of the routed flows and the bypassed flows from Subbasin 3. The program input screen for this example is shown in Figure 7.4.

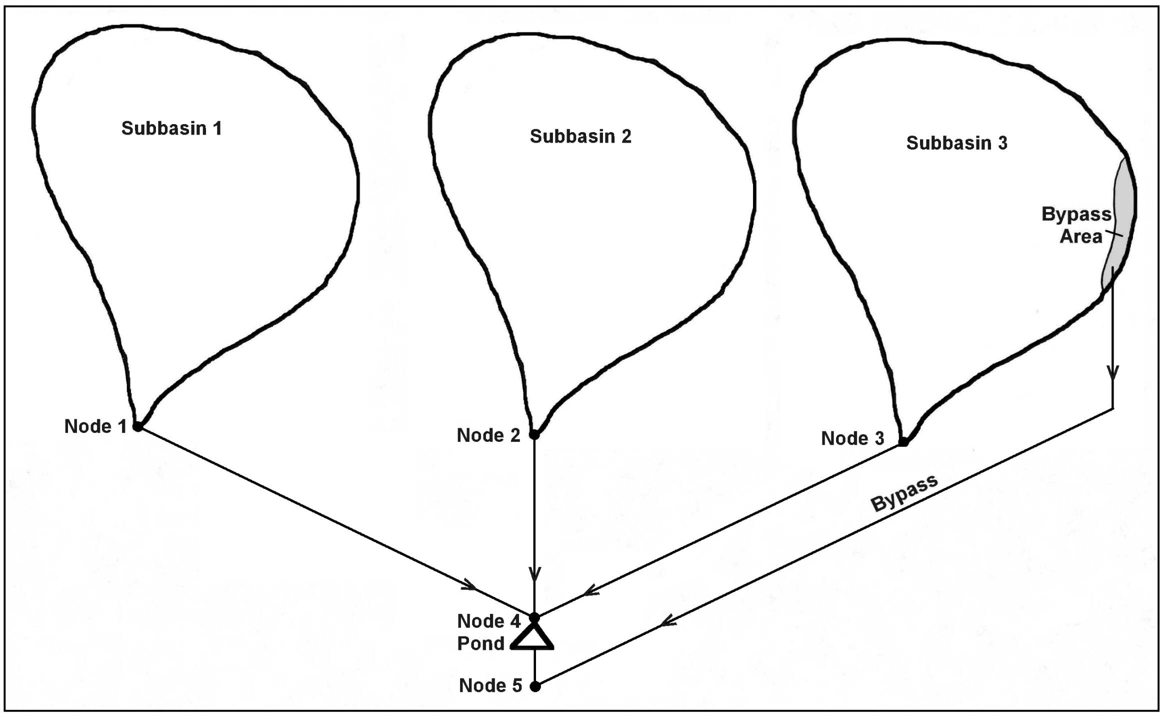


Figure 7.3 – Subbasin/Node Connection Example

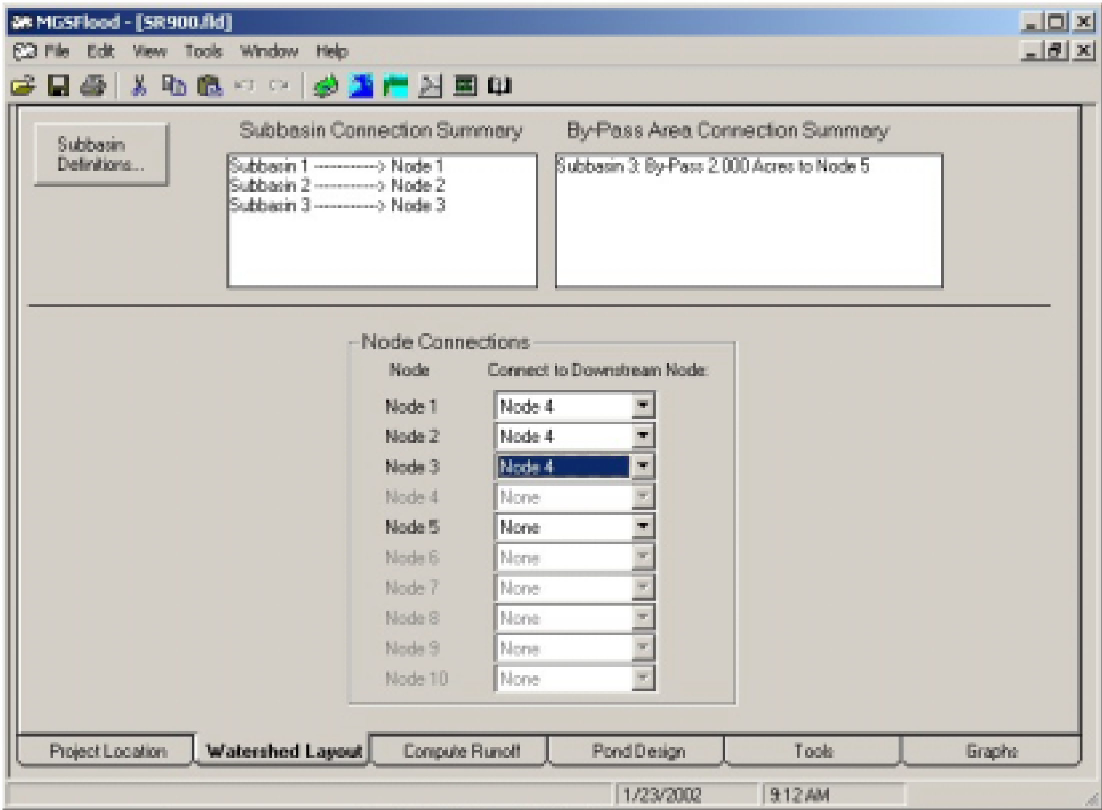


Figure 7.4 – Input Screen for Subbasin/Node Connection Example

8 Compute Runoff Tab

Precipitation and evaporation for the selected climate region are read, and runoff is computed for predevelopment and postdevelopment conditions and saved to a direct access file on disk. The same direct access file is overwritten for each project analyzed by the flood model, i.e., the computed runoff timeseries are not saved for each project. Thus, the runoff must be recomputed before performing any pond design iterations to ensure that the direct access file is up-to-date and contains runoff for the project currently under consideration. The *Compute Runoff* tab is shown in Figure 8.1.

8.1 Specify Time Period for which Runoff is to be Computed

Runoff computations are performed on a *water year* basis, that is, they begin on October 1 and end on September 30. This is done because the soils are typically driest at the beginning of fall and a single set of antecedent conditions can be used for all regions of western Washington. The user can define a time period shorter than the full record for the runoff computations, although the full period of record should be used in facility design to provide the most accurate streamflow computations.

8.2 Specify The Nodes for which Runoff is to be Saved

The runoff computation tab includes check-boxes for selecting those nodes where runoff is to be saved. This feature allows the user to only save runoff from locations of interest in the project, thus reducing the amount of required disk storage.

The node representing the pond inflow must always be saved. If a portion of the site bypasses the pond, then the node representing the bypassed flows must also be saved if they are to be added to the pond outflow. Other nodes may be saved if flow statistics or hydrographs are desired at those locations.

The *Node Name* is a user specified name that is used to help identify the node. This name appears in list boxes that refer to the nodes in other areas of the program and in the Project Documentation Report.

8.3 Compute Runoff Run Button

Clicking the Run button causes runoff to be computed for the period selected and runoff to be saved in the direct access file for the nodes selected. The program then reads the runoff stored in this file for all future pond sizing calculations for the project. If the land use is subsequently changed, the runoff must be recomputed.

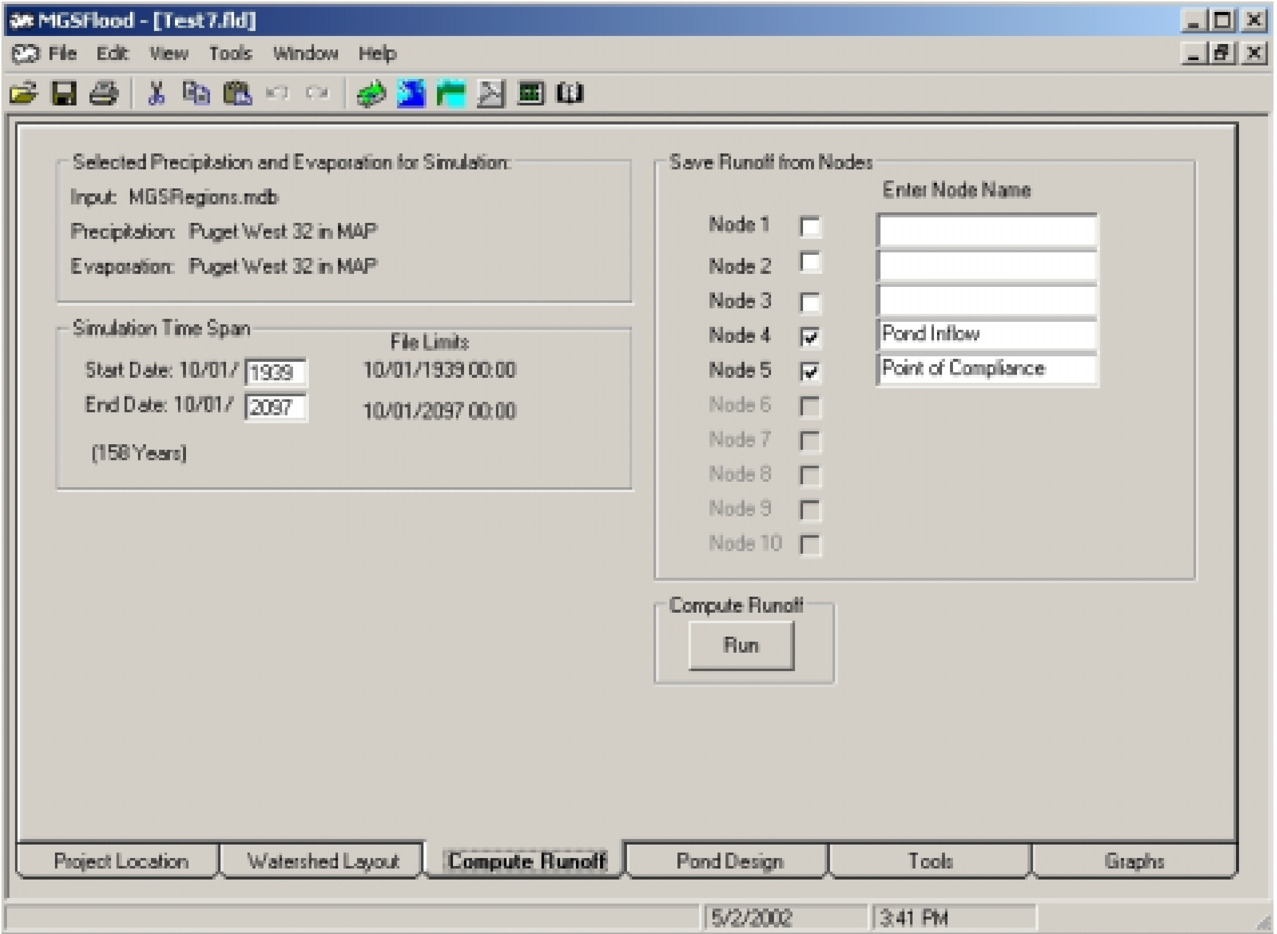


Figure 8.1 – Compute Runoff Tab

9 Pond Design Tab

The pond design tab is used to specify the pond hydraulic characteristics. The pond hydraulics are defined by the *Pond Hydraulic Routing Table* (Figure 9.1).

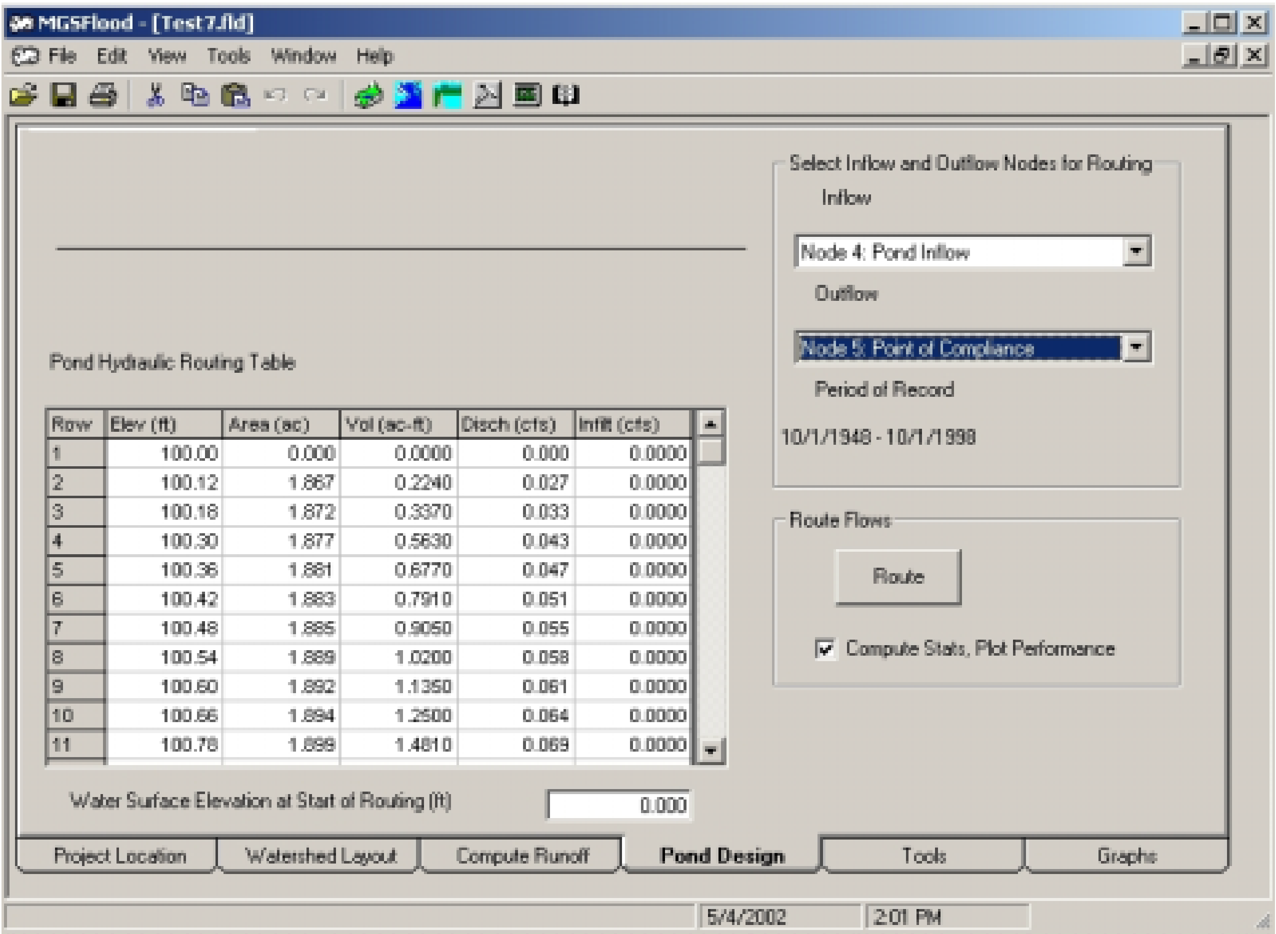


Figure 9.1 – Pond Design Tab

9.1 Inflow and Outflow Nodes for Routing

Runoff from nodes saved on the *Compute Runoff* tab are available for pond routing and are listed on the *Inflow* and *Outflow* list boxes. The pond inflow is defined by selecting a node from the *Inflow* list box. Likewise, the Outflow node list box defines the node that is connected to the pond outflow. Runoff from the node selected on the Outflow list box is added to the pond discharge. In the example shown in Figure 9.1, runoff from Node 5 will be added to the pond discharge. If no nodes are tributary to the pond discharge, then the *Pond Outflow Node* should be selected from the *Outflow* list box (Figure 9.2).

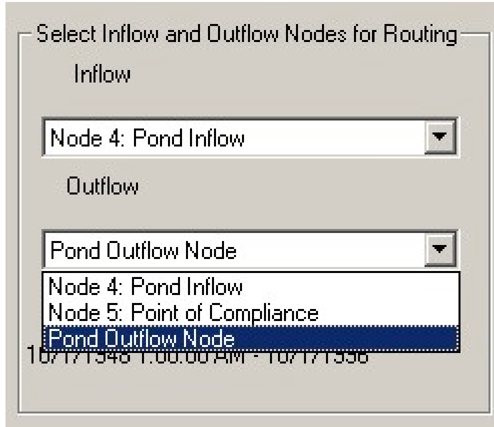


Figure 9.2 – Select *Pond Outflow Node* if no Other Nodes are Tributary to the Pond Outflow

9.2 Route Flows Button

The *Route Flows* button routes the selected inflow timeseries through the pond. The routed flows (with any tributary nodes or bypass nodes added) are then saved to the direct access file on disk and are available for statistical or graphical analyses.

9.3 Pond Design Using Routing Table

Routing is performed using the information entered in the *Hydraulic Routing Table*. Information can be keyed into the table or copied from a spreadsheet and pasted using the Windows clipboard function. *Elevation* is the water surface elevation in the pond, *Area* is the pond surface area (acres), *Volume* is the pond volume (acre-ft), *Discharge* is the pond discharge (cfs), and *Infilt* is infiltration through the pond bottom and/or sides in cfs. Water infiltrated through the pond bottom does not contribute to the computed pond outflow.

10 Tools Tab

The *Tools* tab provides a means to compute statistics on or export flow timeseries computed by the program. In addition, the HSPF runoff parameters can be accessed from this tab. Runoff from nodes saved on the *Compute Runoff* tab are available for statistical analyses or export and are listed on the *Inflow* and *Outflow* list boxes (Figure 10.1). More information on the statistical analyses performed by the program is contained in Part I of the users manual.

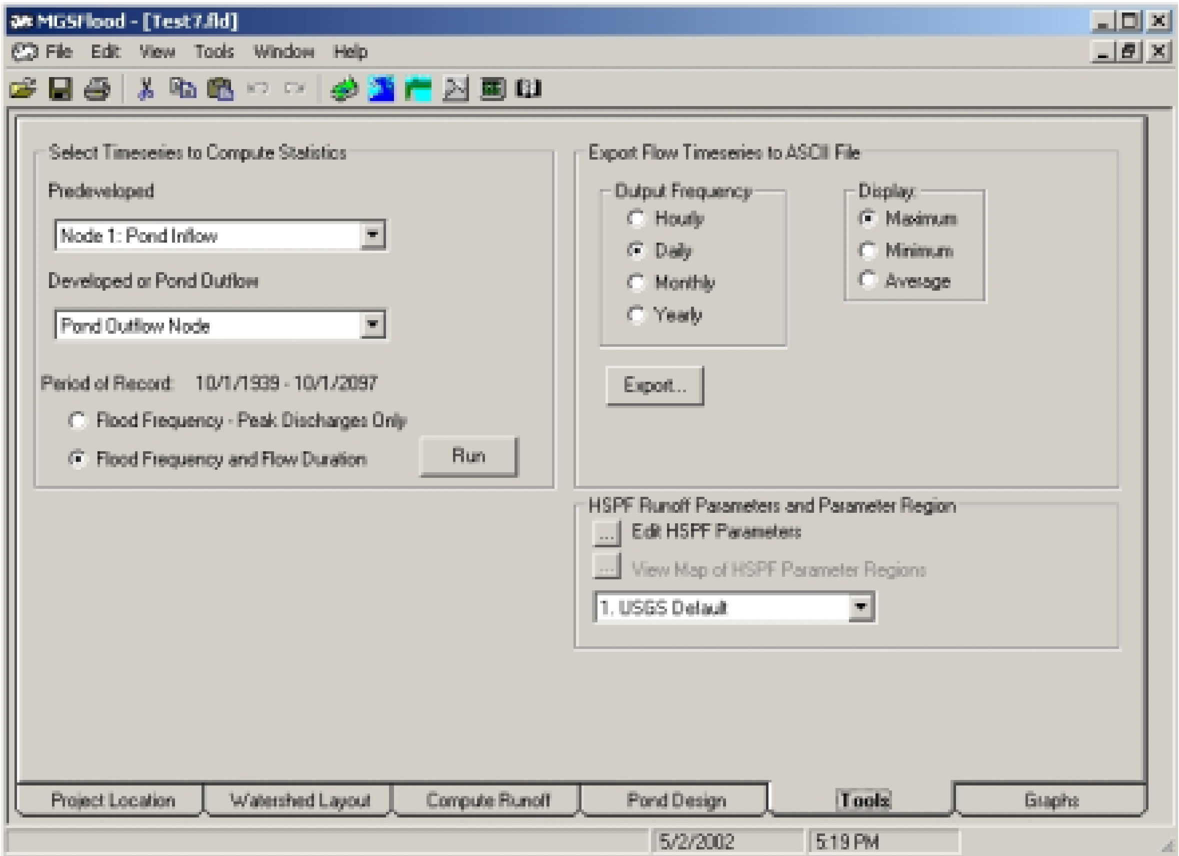


Figure 10.1 – Tools Tab

10.1 Compute Flow Frequency and Duration Statistics for Selected Nodes

To analyze the performance of a stormwater pond in terms of its effectiveness at reducing postdevelopment flows to predeveloped levels, flows are first routed through the pond by clicking the route button on the Pond Design tab. If the *Compute Statistics, Plot Performance* box is checked, the statistics are computed and graphs are created that shows the performance graphically. The pond performance can be assessed by comparing the flow frequency and duration statistics for the pond outflow with the statistics computed for the predeveloped condition.

To compute flood frequency statistics at a particular node, select the node from the list of boxes for predeveloped and postdeveloped land use. Different nodes can be selected for predeveloped and postdeveloped land use if desired. Click the *Run* button to compute statistics. The computed statistics can be viewed by opening the Project Documentation Report or graphically on the *Graphs* tab. If the *Flood Frequency and Flow Duration* option button is selected, then flow duration statistics are computed in addition to flood frequency statistics.

10.2 Export Runoff for Selected Nodes

Runoff for predeveloped and postdeveloped conditions is stored in a direct access file in the program directory. Because this is a binary file, it cannot be viewed with a word processor or text editor. The export utility writes all timeseries stored in this file to an ASCII formatted file for analysis with other programs.

The output frequency option defines the number of time intervals to be aggregated before output is written to the file. For example, if the Daily option button is selected, then runoff will be aggregated and saved to the file once per day. For runoff computed on an hourly time-step, 24 values will be aggregated according to the option selected in the display box. If *Maximum* were selected, then the maximum daily flow would be output, *Minimum* would result in the minimum daily flow, and *Average* would result in the average daily flow.

The output file format consists of the end of period date and time followed by the predeveloped and postdeveloped flows at each node, and the pond outflow and water surface elevation.

<u>Note that the same direct access file is used for each project analyzed by the flood model, i.e. the computed runoff timeseries are not saved for each project. Thus, the runoff must be recomputed before performing any pond design iterations or timeseries export to ensure that the direct access file is up-to-date and contains runoff for the project currently under consideration.</u>

10.3 Runoff Parameter Region, HSPF Parameters

10.3.1 Runoff Parameter Region

MGSFlood can accommodate unique sets of runoff parameters for different regions of western Washington. Currently, only one set of runoff parameters, defined by the USGS, has been defined for use for all of western Washington.

10.3.2 HSPF Parameters

Clicking the Open HSPF Parameters button will display the default runoff parameters for the currently selected region. These parameters should only be modified by those users experienced with HSPF. Any changes to the default runoff parameters will be identified on the project documentation report.

11 Graphs Tab

The *Graphs* tab is used for plotting runoff statistics for nodes selected on the Tools tab, plotting the performance of a stormwater detention pond, or plotting hydrographs from selected nodes. Each time a graph is created, a copy of the graph is stored in the project subdirectory in a jpeg-formatted file.

Statistics are plotted for nodes selected on either the *Pond Design* or *Tools* tabs depending on which of the following operations was last performed:

- If runoff was routed through the pond with the *Compute Stats Plot Performance* box checked, then runoff statistics for the nodes selected on the *Pond Design* tab are plotted,
- If statistics were computed from the *Tools* tab, then runoff statistics for the nodes selected on the *Tools* tab are plotted.

11.1 Flood Frequency Statistics Graphs

Flood frequency statistics are plotted by selecting the *Flood Frequency* option button and clicking the *Draw* button. Each time the draw button is clicked, the graph on the screen and the jpeg file on disk are each updated.

11.2 Flow Duration Statistics Graphs

Flow duration statistics are plotted by selecting the *Flow Duration* option button and clicking the *Draw* button. Each time the draw button is clicked, the graph on the screen is updated and the graph is stored onto disk as a jpeg file. The flow duration graph includes annotations noting the predeveloped ½ of the 2-year, 2-year and the 50-year flows, the exceedance probability corresponding to these flows, whether the Department of Ecology Flow Duration criteria[9] have been met, and the maximum water surface elevation occurring in the pond during the simulation (Figure 11.1).

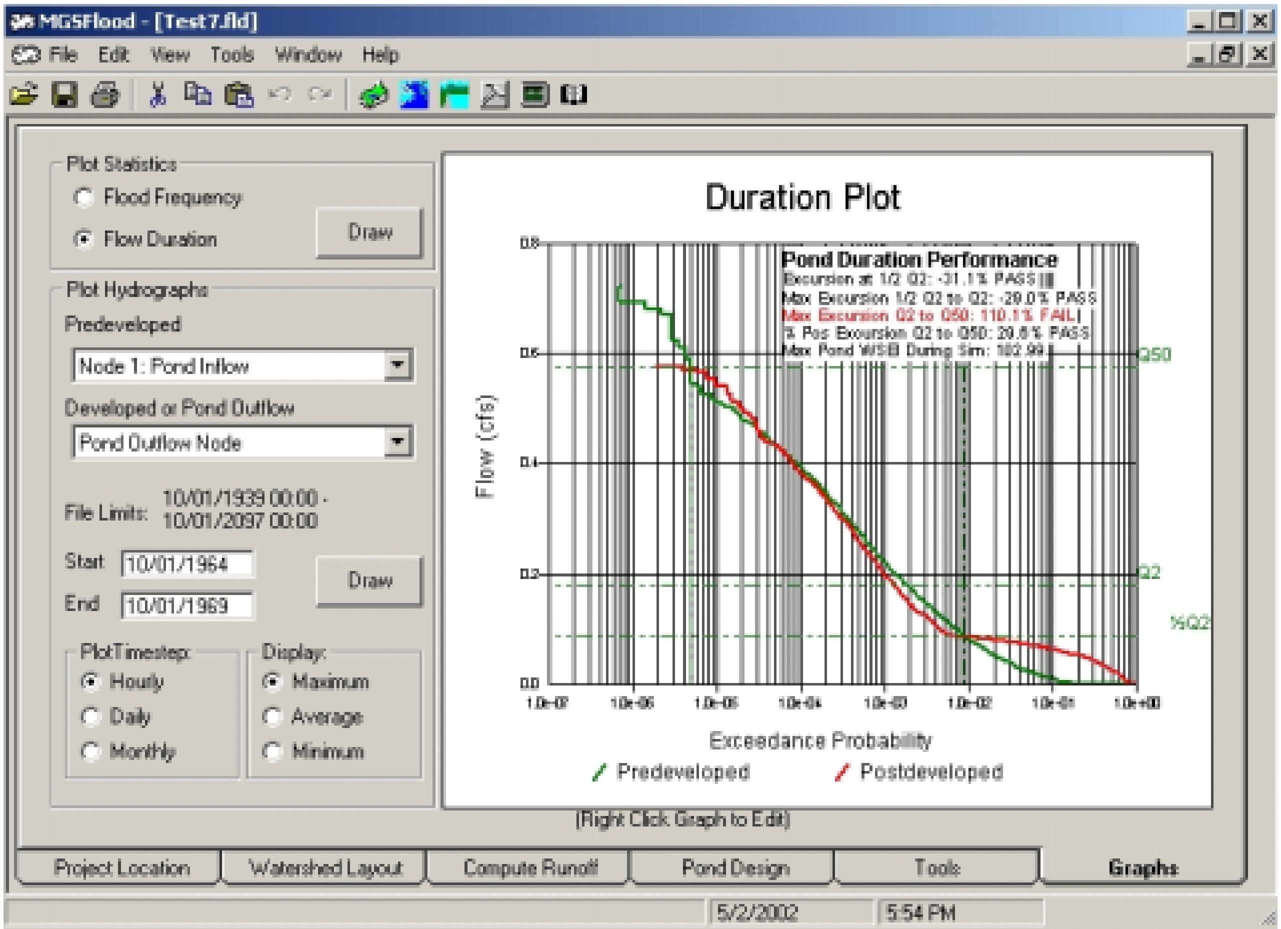


Figure 11.1 – Flow Duration Graph Showing Pond Performance

11.3 Hydrographs

Runoff from nodes saved on the *Compute Runoff* tab are available for display as hydrographs on the *Graphs* tab. One predeveloped and one postdeveloped timeseries can be displayed on the graph. Any time period, within the period of record saved in the direct access file, can be plotted. The *Plot Timestep* defines the number of time intervals to be aggregated before output is written to the file. For example, if *Daily* is selected then runoff for each day will be aggregated before outputting. If the runoff was computed at a 1-hour timestep, then 24 values will be aggregated according to the *Aggregate* option selected. If *Maximum* were selected, then the maximum flow would be plotted, *Minimum* would result in the minimum flow, and *Average* would result in the average flow.

11.4 Customizing Graphs

The titles on graphs can be changed or modified by clicking the right mouse button on the graph. This will display the *Graph Settings* screen where the graph titles and other settings can be changed (Figure 11.2).

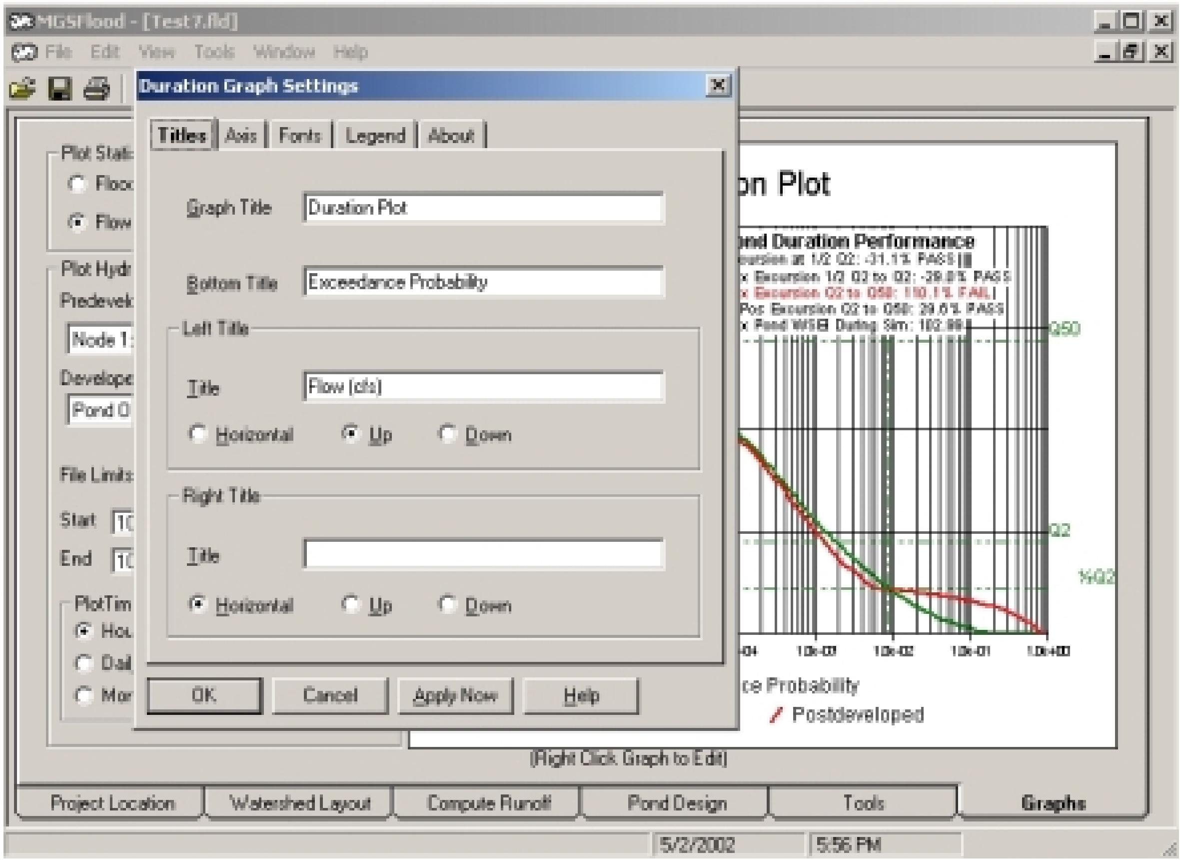
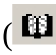


Figure 11.2 – Graphs Settings Screen Displayed by Clicking the Right Mouse Button on the Graph

12 Creating/Viewing the Project Documentation Report

The project reporting utility creates a report that documents all model inputs, stormwater pond design information, and frequency and duration statistics. The report is created and viewed on screen by selecting *View Report* from the File menu or from the *View Report* icon () on the tool bar. The report can be printed by selecting *Print Report* from the File menu. When the project report is printed, any frequency and duration graph images stored in the project directory are also printed. These images represent the latest graphs plotted from the Graphs tab. Each time the report is viewed or printed, a copy of the report is stored in a file with the name <*ProjectName.rtf*> in the project data directory. This file can be viewed with a text editor or imported into word processor or spreadsheet program.